Frontiers of Quantum and Mesoscopic Thermodynamics

25 - 30 July 2011, Prague, Czech Republic

Under the auspices of

Milan Štěch
President of the Senate of the Parliament of the Czech Republic

Prof. Ing. Jiří Drahoš, DrSc., dr. h. c.
President of the Academy of Sciences of the Czech Republic

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

Supported by

- Committee on Education, Science, Culture, Human Rights and Petitions of the Senate of the Parliament of the Czech Republic
- Institute of Physics, the Academy of Sciences of the Czech Republic
- Faculty of Mathematics and Physics, Charles University, Czech Republic
- Institute for Theoretical Physics, University of Amsterdam, The Netherlands
- Department of Physics, Texas A&M University, USA
- Institut de Physique Théorique, CEA/CNRS Saclay, France

Topics

- Foundations of quantum physics
- Non-equilibrium quantum statistical physics
- Quantum thermodynamics
- Quantum measurement, entanglement and coherence
- Dissipation, dephasing, noise and decoherence
- Quantum optics
- Macroscopic quantum behavior, e.g. cold atoms, Bose-Einstein condensates
- Physics of quantum computing and quantum information
- Mesoscopic, nano-electromechanical and nano-optical systems
- Spin systems and their dynamics
- Biological systems, molecular motors
- Cosmology, gravitation and astrophysics

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- Institute of Physics, the Academy of Sciences of the Czech Republic
- Faculty of Mathematics and Physics, Charles University, Czech Republic
- Committee on Education, Science, Culture, Human Rights and Petitions of the Senate of the Parliament of the Czech Republic
- Music Bridges International, New York, USA

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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 size. 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, proteins and viruses.

There is thus a growing demand for an understanding of the laws which govern the behavior of these systems. The development of theoretical concepts for their description and reliable experimental methods is of great importance for investigating these systems and designing new nanostructures with well defined, desired behavior.

The conference will address the foundations of quantum physics and non-equilibrium quantum statistical physics. The systems considered will be mainly on the order of mesoscopic (nanoscale) size, and include those of both natural and artificial origin. The main goal of the conference is to contribute to the uncovering of possible phenomenological ("quantum thermodynamic") laws governing the behavior of mesoscopic systems, and to provide better understanding and insight into the recent problems of the foundations, relying on the theoretical and experimental methods of condensed matter physics and quantum optics. Special attention will be given to the dynamics of mesoscopic open systems and their relevance to problems of measurement of non-equilibrium quantum systems, thermal and quantum fluctuations, dissipation, noise, physics of quantum information and biological systems, in terms of both theory and experiment. Additional subjects will include biophysics, gravitation and cosmology.

FQMT'11 is a follow-up to the two previous, successful Prague conferences "Frontiers of Quantum and Mesoscopic Thermodynamics 2004" (FQMT'04), and "Frontiers of Quantum and Mesoscopic Thermodynamics 2008" (FQMT'08). As in FQMT'04 and in FQMT'08, the aim of FQMT'11 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. Many aspects of the FQMT topics have been covered by a number of recent, more specialized, conferences and workshops which the organizers of the FQMT conferences have taken an essential part in, namely Hot topics in Quantum Statistical Physics: q-thermodynamics, q-decoherence and q-motors, Leiden 2003; Non-equilibrium Green's Functions I-IV conferences, Rostock 1999, Dresden 2002, Kiel 2005, and Glasgow 2009; Conferences on the Second Law of Thermodynamics and Quantum Physics, San Diego 2002, and 2006; Beyond the Quantum, Leiden 2006; and the Vaxjö meetings on Quantum Theory: Reconsideration of Foundations, Vaxjö 2001, 2003, 2005, 2007, and 2009.

The conference is intended to bring together a unique combination of young and experienced scientists across a disciplinary spectrum ranging from foundations of quantum physics to emerging statistical physics approaches to the study of non-equilibrium quantum systems. As in FQMT'04 and FQMT'08, the interdisciplinary character of the conference will be 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 a broader perspective of overlap with other fields. It is an objective to gather important scientists from overlapping branches of physics who can mutually benefit from the exchange of different views, experiences from studies of many different systems and various theoretical and experimental approaches to the study of current problems in physics. 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, quantum statistical physics of finite systems far from equilibrium and the physics of nanoscale systems, and further, will motivate new collaboration and intensive discussions between experts from differing fields (i.e., physics, chemistry, biology and cosmology).

In keeping with the multidisciplinary character of the scientific program, the cultural richness of the city of Prague and the tradition of the previous FQMT conferences, the FQMT'11 program will feature concerts of classical and jazz music performed by world-class musicians, held at outstanding venues of the city. Both the scientific program and the musical program are intended as a complement to one another, where scientists and musicians are encouraged to mingle and share their knowledge and experience.

To this end, the organizers have endeavored to create a program which covers all topics of the program. 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 25, till Saturday, July 30 in the Pyramida Hotel. Every morning or afternoon session will be devoted to a specific topic.

Dear colleague, we welcome you to the FQMT'11 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'11 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

First public lecture and classical concert will take place at:
St. Simon and Juda Church
address: Dušní ulice, Praha 1 - Staré Město

Second public lecture and classical concert will take place at:
Dvořák's Hall of Rudolfinum
address: Palachovo náměstí, Praha 1 - Staré Město

The FQMT'11 conference dinner will take place at:
Vikárka Restaurant
address: Vikářská 39, Praha 1 (Prague Castle)

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). There is a possibility that all participants will have 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

Pyramida Hotel

- Pyramida Congress Hall (ground floor): Most lectures will be presented there
- Smaller halls will be used for some parallel sessions
- Lobby of Pyramida Congress Hall (ground floor): it will serve as a coffee room; tea and coffee will be available there all time
- Several other rooms will be available for the FQMT'11 participants

Posters

Poster session will be held on Wednesday (July 27). Posters can be fixed from 7:30 a.m. on Wednesday on the first floor (corridors) of the Pyramida Hotel and can be exhibited till Friday 11 a.m.

Social Events

- Tour of the Wallenstein Palace: Wallenstein Palace, Monday July 25
- Welcome party: Wallenstein Palace Garden, Monday July 25
- First evening lecture: St. Simon and Juda Church, Tuesday July 26
  This evening lecture will be given by Martin Rees.
- Classical music concert: St. Simon and Juda Church, Tuesday July 26
- Jazz concert: Cinema Hall of the Pyramida Hotel, Wednesday July 27

- Second evening lecture: Dvořák's Hall of Rudolfinum, Thursday July 28
  This evening lecture will be given by Claude Cohen-Tannoudji.
- Classical music concert: Dvořák's Hall of Rudolfinum, Thursday July 28
- Conference dinner: Vikárka Restaurant, Friday July 29
- Classical music concert: St. Vitus Cathedral, Friday July 29

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

Food

Lunches:

All participants can use either

- a possibility to buy during their registration on Sunday or Monday tickets for lunches in the restaurant just in the hotel Pyramida.
  The price of one lunch will be 15 EUR.

  or

- to 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:** There will be enough time to go for dinner before the public lecture of Martin Rees, either in the **Pyramida Hotel** or to various restaurants in the vicinity of the Pyramida Hotel. It is also possible to go for dinner to numerous restaurants in the Old Town area (near St. Simon and Juda Church).
- **Wednesday:** Buffet during the poster session in the **Pyramida Hotel**.
- **Thursday:** There will be enough time to go for dinner before the public lecture of Claude Cohen-Tannoudji, either in the **Pyramida Hotel** or to various restaurants in the vicinity of the Pyramida Hotel. It is also possible to go for dinner to numerous restaurants in the Old Town area (near the Rudolfinum).
- **Friday:** Conference dinner in the **Vikárka Restaurant at Prague Castle**.
  Price: 60 EUR per person - tickets for this dinner will be available during the registration.

PROGRAM

Sunday, 24 July 2011

17:00 – 21:00 Registration and welcome refreshment
Location: Pyramida Hotel - lobby

Monday, 25 July 2011

08:00 – 8:30 **Opening addresses**

Location: Pyramida Hotel Lecture Hall

08:30 – 10:00 **1 session: Foundations of quantum mechanics**

Location: Pyramida Hotel Lecture Hall

08:30 – 09:00	Anton Zeilinger:	*Recent experiments with photons: Testing the foundations of quantum physics and developing new tools for quantum information*
09:00 – 09:30	Juerg Froehlich:	*Quantum friction and quantum Brownian motion*
09:30 – 10:00	Markus Aspelmeyer:	*How to extend quantum experiments to massive mechanical objects: Prospects and challenges*

10:00 – 10:20 Coffee break

10:20 – 12:00 **2 session: Foundations of quantum mechanics**

Location: Pyramida Hotel Lecture Hall

10:20 – 10:50	Gordon Baym:	*Two-slit diffraction with highly charged particles: Niels Bohr's consistency argument that the electromagnetic field must be quantized*
10:50 – 11:20	Kimball Milton:	*Thermal issues in Casimir forces between conductors and semiconductors*
11:20 – 11:40	Karl Hess:	*Hidden assumptions in proofs of Bell*
11:40 – 12:00	Theo Nieuwenhuizen:	*Dynamics in a model for quantum measurements and insight in the quantum measurement problem*

12:00 – 13:00 Lunch

13:00 – 15:00 **3 session: Foundations of quantum mechanics**

Location: Pyramida Hotel Lecture Hall

13:00 – 13:30	Ralf Schuetzhold:	*Fundamental quantum effects in the laboratory*

13:30	–	14:00	Ana María Cetto:	*Implications of radiative corrections for the particle-zeropoint field system: establishing contact with quantum electrodynamics*
14:00	–	14:30	Andrei Khrennikov:	*QM as theory of classical signals with noisy background*
14:30	–	15:00	Victor Flambaum:	*Evidence for spatial variation of the fine structure constant*
15:00	–	15:20	Coffee break	

15:20 – 17:00 **4 session: Quantum thermodynamics**

Location: Pyramida Hotel Lecture Hall

15:20	–	15:50	Howard Wiseman:	*Quantum jumps in non-thermal-equilibrium systems: How far beyond Einstein do we need to go?*
15:50	–	16:20	Gershon Kurizki:	*Quantum engines via measurements on non-Markovian time scales*
16:20	–	16:40	Noam Erez:	*Thermodynamics of quantum measurements*
16:40	–	17:00	Lawrence Schulman:	*Non-thermodynamic behavior for non-ergodic interactions: Violation of the 0th law*
17:00	–	17:45	Free time and transfer to Wallenstein Palace	
17:45	–	19:30	Guided tour through Wallenstein Palace	
19:30	–	23:00	Welcome party in the Wallenstein Palace Garden	

Tuesday, 26 July 2011

08:00 – 10:00 **1 session: Physics of quantum computing**

Location: Pyramida Hotel Lecture Hall

08:00 – 08:30	Peter Zoller:	*Engineered dissipation for quantum information and many body physics*
08:30 – 09:00	Denis Vion:	*Towards hybrid quantum circuits: Strong coupling of a spin ensemble to a superconducting resonator*
09:00 – 09:20	Giuseppe Falci:	*Quantum coherence in nanofabricated three-level artificial atoms*
09:20 – 09:40	Amnon Aharony:	*Retrieving quantum qubit information despite decoherence*
09:40 – 10:00	Timothy C. Ralph:	*Relativistic quantum information*

10:00 – 10:20 Coffee break

10:20 – 12:00 **2 session: Quantum measurement, entanglement and coherence**

Location: Pyramida Hotel Lecture Hall

10:20 – 10:50	Barry Sanders:	*Efficient algorithm for optimizing adaptive quantum metrology processes*
10:50 – 11:20	Andrew Jordan:	*Precision measurements and weak values*
11:20 – 11:40	Alessandro Romito:	*Weak values in solid state systems: Charge sensing amplification and decoherence effects*
11:40 – 12:00	Elisabetta Paladino:	*Degradation and protection of entanglement between solid state qubits*

12:00 – 13:00 Lunch

13:00 – 15:20 **3 session - A parallel: Mesoscopic systems**

Location: Pyramida Hotel Lecture Hall

13:00 – 13:20	Frithjof Anders:	*Nonequilibrium Zeeman-splitting in quantum transport through nanoscale junctions*
13:20 – 13:40	Michael Galperin:	*Raman spectroscopy of molecular junctions*
13:40 – 14:00	Sense Jan van der Molen:	*Quantum interference in molecular junctions*
14:00 – 14:20	Fabio Taddei:	*Blockade and counterflow supercurrent in exciton-condensate Josephson junctions*

14:20	–	14:40	Avraham Schiller:	*From the adiabatic to the anti-adiabtic regime of phonon-assisted tunneling*
14:40	–	15:00	Frank Hekking:	*Circuit approach to photonic heat transport*
15:00	–	15:20	Rafael Sánchez:	*Transport from hot spots*

13:00 – 15:00 **3 session - B parallel: Quantum optics**

Location: Pyramida Hotel Cinema Hall

13:00	–	13:20	Joshua A. Slater:	*Broadband waveguide quantum memory for entangled photons*
13:20	–	13:40	Anil K. Patnaik:	*Ultrafast thermometry using quantum coherence*
13:40	–	14:00	Radim Filip:	*Quantum and semiclassical noiseless amplifier*
14:00	–	14:20	Jeremy Amstrong:	*Bound states in multilayers of cold polar molecules*
14:20	–	14:40	Mark Fox:	*Phonon damping and renormalization of Rabi oscillations in InGaAs quantum dots*
14:40	–	15:00	Howard Carmichael:	*Elastic light scattering from multi-level atoms: Ground-state quantum beats and evolution of coherence through quantum jumps*
15:20	–	18:30	Free time and transfer to St. Simon and Juda Church	

18:30 – 22:20 **Evening session: Public lecture of Martin Rees and concert**

Location: St. Simon and Juda Church

18:30	–	18:45	Music introduction and opening address	
18:45	–	20:00	Public lecture	
18:45	–	19:45	Martin Rees:	*From Big Bang to biospheres*
19:45	–	20:00	Discussion after the lecture of Martin Rees	
20:00	–	20:20	Break	
20:20	–	21:10	**Concert of classical music - first part**	
21:10	–	21:30	Break	
21:30	–	22:20	**Concert of classical music - second part**	

Wednesday, 27 July 2011

08:00	–	10:00	**1 session: Nonequilibrium quantum statistical physics**	
			Location: Pyramida Hotel Lecture Hall	
08:00	–	08:30	Ulrich Weiss:	*Nonlinear quantum transport and noise statistics*
08:30	–	09:00	Yuli Nazarov:	*Flows of quantum information quantities*
09:00	–	09:30	Yoseph Imry:	*Slow relaxation and aging in the electron glass*
09:30	–	10:00	Tamar Seideman:	*Driven electrons in strong laser fields*
10:00	–	10:20	Coffee break	
10:20	–	12:00	**2 session - A parallel: Foundations of quantum mechanics**	
			Location: Pyramida Hotel Lecture Hall A	
10:20	–	10:40	Kristel Michielsen:	*Testing the applicability of quantum theory to event-based processes*
10:40	–	11:00	Hans De Raedt:	*Towards a corpuscular event-by-event simulation of optical phenomena*
11:00	–	11:20	Luis de la Peña:	*Quantum nonlocality revisited from the point of view of a local stochastic theory*
11:20	–	11:40	Čestmír Šimáně:	*Mesic forces in quantum mechanics*
11:40	–	12:00	Miloš Lokajíček:	*Controversy between Einstein and Bohr after 75 years, its actual solution and the consequences for the present*
10:20	–	12:00	**2 session - B parallel: Mesoscopic systems**	
			Location: Pyramida Hotel Lecture Hall B	
10:20	–	10:40	Andreas Wacker:	*Coherent tunneling and canyon of current suppression in quantum dots*
10:40	–	11:00	Jan von Delft:	*The 0.7-anomaly in quantum point contacts: Evidence for a Nozières' Fermi liquid*
11:00	–	11:20	Daniel Sheehan:	*Diodic electric fields in NEMS/MEMS devices: Toward a solid-state second law challenge*
11:20	–	11:40	Peter Keefe:	*Relaxation phenomena in the adiabatic phase transition of Type I superconductor particles*

11:40	–	12:00	Howard Brandt:	*Microcausality in quantum field theory*

10:20 – 12:00 **2 session - C parallel: Dissipation, noise and decoherence**

Location: Pyramida Hotel Conference Room 3

10:20	–	10:40	Andrew Armour:	*Noise properties of cavity-driven mechanical oscillations*
10:40	–	11:00	Tomáš Novotný:	*Inelastic effects on the electronic current noise through nanojunctions*
11:00	–	11:20	Lea Santos:	*Quantum chaos and thermalization in isolated many-body systems*
11:20	–	11:40	Andrei Zaikin:	*Persistent current noise and electron-electron interactions*
11:40	–	12:00	Francesco Petruccione:	*Open quantum random walks*
12:00	–	13:00	Lunch	

13:00 – 15:00 **3 session - A parallel: Nonequilibrium quantum statistical physics**

Location: Pyramida Hotel Lecture Hall A

13:00	–	13:20	James Freericks:	*Theory of time-resolved photoemission spectroscopy*
13:20	–	13:40	Peter Schmitteckert:	*Transport in and through correlated nanostructures: A density matrix renormalization group perspective*
13:40	–	14:00	Claudio Verdozzi:	*TDDFT and Green's function dynamics for strongly correlated model systems*
14:00	–	14:20	Bozidar Novakovic:	*Transient-regime transport in nanostructures*
14:20	–	14:40	Václav Špička:	*Fast dynamics of molecular bridges*
14:40	–	15:00	Bedřich Velický:	*Vibronic effects in transient behavior of molecular bridges*

13:00 – 15:00 **3 session - B parallel: Mesoscopic systems**

Location: Pyramida Hotel Lecture Hall B

13:00	–	13:20	Joachim Ankerhold:	*Optimal control of open quantum systems in non-Markovian environments*
13:20	–	13:40	Fabrice Debbasch:	*Continuous limit of discrete time quantum walks*

13:40	–	14:00	Dragos Victor Anghel:	*A new paradigm to describe mesoscopic systems by employing fractional exclusion statistics*
14:00	–	14:20	Sigmund Kohler:	*Graphene ratchets*
14:20	–	14:40	Jerzy Łuczka:	*Indirect control of anomalous transport in a system of two coupled Brownian particles*
14:40	–	15:00	Jiří J. Mareš:	*Quantum thermostatics and generalization of Wien's law*

13:00 – 15:00 **3 session - C parallel: Spins systems, cold atoms, quantum optics**

Location: Pyramida Hotel Conference Room 3

13:00	–	13:20	Gilles Montambaux:	*Engineering of Dirac cones in two-dimensional crystals*
13:20	–	13:40	Thomas Schmidt:	*Spin-charge separation in one-dimensional fermion systems beyond Luttinger liquid theory*
13:40	–	14:00	Jorge Dukelsky:	*Phase diagram of the integrable px+ipy fermionic superfluid*
14:00	–	14:20	Alexander Altland:	*Anderson transition in the cold atom kicked rotor*
14:20	–	14:40	Norbert Kroo:	*Some novelties in nonlinear plasmonics*
14:40	–	15:00	Yuri Rostovtsev:	*Mechanism of anomalous heating of trapped ions*

15:00 – 15:20 Coffee break

15:20 – 17:00 **4 session - A parallel: Physics of quantum computing**

Location: Pyramida Hotel Lecture Hall A

15:20	–	15:40	Jens Koch:	*Superconducting qubits grow up: Quantum coherence in circuits with many degrees of freedom*
15:40	–	16:00	Alex Retzker:	*Quantum computing with magnetic insensitive states*
16:00	–	16:20	Robert O'Connell:	*Entanglement and coherence: Differences and similarities*
16:20	–	16:40	Igor Pikovski:	*Probing the canonical commutator of massive mechanical oscillators*
16:40	–	17:00	Christoph Bruder:	*Quantum control of interacting qubits*

15:20 – 17:00	**4 session - B parallel: Spin systems, dissipation and noise**	
	Location: Pyramida Hotel Lecture Hall B	
15:20 – 15:40	Ora Entin-Wohlman:	*Spin-polarized electric currents in quantum transport*
15:40 – 16:00	Vadim Cheianov:	*Statistical mechanics of magnetic impurities on graphene*
16:00 – 16:20	Doron Cohen:	*Quantum vs stochastic non-equilibrium steady state of driven systems*
16:20 – 16:40	Boris Fine:	*Emergence of non-thermal statistics in isolated many-particle quantum systems after multiple perturbations*
16:40 – 17:00	Eugene Sukhorukov:	*Energy relaxation at the quantum Hall edge*

15:20 – 17:00	**4 session - C parallel: Cosmology, gravitation and astrophysics**	
	Location: Pyramida Hotel Conference Room 3	
15:20 – 15:40	Rudy Schild:	*Observations of Black Holes show the possibility of a widely separated accretion disk*
15:40 – 16:00	Fumio Abe:	*MOA II gravitational microlensing survey*
16:00 – 16:20	Hao Liu:	*Systematical effects in WMAP data and looking forward to the Planck data release*
16:20 – 16:40	Carl H. Gibson:	*Hydro-gravitational-dynamics of the cosmological big bang and the biological big bang*
16:40 – 17:00	Nalin Wickramasinghe:	*Biology: A cosmological constraint?*

17:00 – 20:00	**Poster session**
	Location: Pyramida Hotel - first floor
17:00 – 20:00	Refreshment
20:00 – 23:00	**Jazz concert**
	Location: Pyramida Hotel Cinema Hall

Thursday, 28 July 2011

08:00 – 10:00	**1 Session: Quantum optics**	
	Location: Pyramida Hotel Lecture Hall	
08:00 – 08:30	Immanuel Bloch:	*Controlling and imaging quantum gases at the single atom level*
08:30 – 09:00	Thomas Udem:	*A phonon laser*
09:00 – 09:30	Gerd Schön:	*Lasing and transport in a quantum dot-resonator circuit*
09:30 – 10:00	Helmut Rauch:	*Hadron interferometry with neutrons*
10:00 – 10:20	Coffee break	
10:20 – 12:00	**2 session: Macroscopic quantum behaviour and cold atoms**	
	Location: Pyramida Hotel Lecture Hall	
10:20 – 10:50	Linda Elizabeth Reichl:	*Relaxation processes in a Bose-Einstein condensate*
10:50 – 11:20	Fernando Sols:	*Quantum transport of cold atoms*
11:20 – 11:40	Eric Akkermans:	*Bose-Einstein condensation, Casimir forces and quantum optics on fractal structures*
11:40 – 12:00	Stephanie Reimann:	*Dipolar quantum gases from a few-body perspective*
12:00 – 13:00	Lunch	
13:00 – 15:00	**3 session: Macroscpic quantum behaviour, interference, dissipation and noise**	
	Location: Pyramida Hotel Lecture Hall	
13:00 – 13:30	Pascal Simon:	*Bose Fermi mixture in a disordered one dimension potential: The Bose Fermi glass*
13:30 – 14:00	Gregor Weihs:	*Multi-order interference and Born's rule*
14:00 – 14:30	Wolfgang Belzig:	*Quasiprobability and quantum paradoxes in electronic counting statistics*
14:30 – 15:00	Moty Heiblum:	*Observation of 'neutral modes' in the QHE regime via shot noise measurements*
15:00 – 18:30	Free time and transfer to Rudolfinum	

18:30	–	21:40	**Evening session: Public lecture of Claude Cohen-Tannoudji and concert**
			Location: Rudolfinum - Dvořák's Hall
18:30	–	18:45	Music introduction and opening address
18:45	–	20:00	Public lecture
18:45	–	19:45	Claude Cohen-Tannoudji: *Laser manipulation of atoms*
19:45	–	20:00	Discussion after the lecture of Claude Cohen-Tannoudji
20:00	–	20:20	Break
20:20	–	21:40	**Concert of classical music**

Friday, 29 July 2011

08:00	–	10:00	**1 session: Spin systems and their dynamics**	
			Location: Pyramida Hotel Lecture Hall	
08:00	–	08:30	Yoram Alhassid:	*The coexistence of superconductivity and ferromagnetism in nanoscale metallic grains*
08:30	–	09:00	Dietrich Belitz:	*Phases, broken symmetries, and Goldstone modes in helical magnets*
09:00	–	09:20	Ted Kirkpatrick:	*Generic non-Fermi-liquid behavior in metallic helimagnets*
09:20	–	09:40	Thomas Vojta:	*Anomalously elastic, intermediate phase in randomly layered superfluids, superconductors, and planar magnets*
09:40	–	10:00	Branislav K. Nikolic:	*Spin pumping in magnetic tunnel junctions and topological insulators: Theory and experiment*
10:00	–	10:20	Coffee break	
10:20	–	12:00	**2 session: Non-equilibrium statistical physics**	
			Location: Pyramida Hotel Lecture Hall	
10:20	–	10:50	Miguel Rubi:	*Mesoscopic non-equilibrium thermodynamics*
10:50	–	11:20	Udo Seifert:	*Optimization in stochastic thermodynamics: Efficiency of nano-machines (at maximum power)*
11:20	–	11:40	Eric Lutz:	*Nonequilibrium entropy production for open quantum systems*
11:40	–	12:00	Jens Eisert:	*Relaxation, thermalization, and a quantum algorithm to prepare Gibbs states*
12:00	–	13:00	Lunch	
13:00	–	15:00	**3 session: Non-equilibrium statistical physics**	
			Location: Pyramida Hotel Lecture Hall	
13:00	–	13:30	Pawel Danielewicz:	*Advancing quantum transport for nuclear reactions*

13:30	–	14:00	Stefano Sanvito:	*Electron transport in large systems including fluctuating environment and many body effects*
14:00	–	14:30	Antti-Pekka Jauho:	*Heat conduction in nanostructured graphene*
14:30	–	15:00	Dietrich Kremp:	*Bound states in non-equilibrium statistical physics*

15:00 – 15:20 Coffee break

15:20 – 17:20 **4 session: Quantum measurement, entanglement and coherence**

Location: Pyramida Hotel Lecture Hall

15:20	–	15:50	Dirk Bouwmeester:	*Towards quantum superpositions of a mirror*
15:50	–	16:20	Paul G. Kwiat:	*Finding hidden entanglement*
16:20	–	16:40	Julien Laurat:	*Quantum-to-classical transition of single-photon counters*
16:40	–	17:00	Jean-Daniel Bancal:	*Device independent witnesses for genuine multipartite entanglement*
17:00	–	17:20	Bruno Sanguinetti:	*Can one see entanglement?*
17:20	–	18:30	Free time and transfer to Prague Castle	

18:30 – 24:00 **Conference dinner and concert**

Location: Prague Castle - Vikárka Restaurant and St. Vitus Cathedral

18:30	–	20:30	First part of the conference dinner
20:30	–	21:50	**Concert in St. Vitus Cathedral**
21:50	–	24:00	Second part of the conference dinner

Saturday, 30 July 2011

08:00 – 10:00	**1 session: Biological systems, molecular motors**	
	Location: Pyramida Hotel Lecture Hall	
08:00 – 08:30	Andrew White:	*Simulating quantum systems in biology, chemistry and physics*
08:30 – 09:00	Stefan Klumpp:	*Mechanisms and economy of molecular machines*
09:00 – 09:30	Hans Frauenfelder:	*Quasielastic spectra in the Mössbauer effect and neutron scattering*
09:30 – 10:00	Michael Bonitz:	*Strongly correlated few-fermion systems: From equilibrium properties to ultrafast dynamics*
10:00 – 10:20	Coffee break	
10:20 – 12:00	**2 session: Foundations of quantum mechanics, macroscopic quantum behavior**	
	Location: Pyramida Hotel Lecture Hall	
10:20 – 10:50	Arkady Plotnitsky:	*What is quantum field theory, technologically, mathematically, and philosophically?*
10:50 – 11:20	Raymond Y. Chiao:	*Generation of gravitational radiation via superluminal quantum mass currents*
11:20 – 11:40	Stephen J. Minter:	*Using macroscopic discontinuities in magnetic susceptibility within a loop of type-II superconducting wire to measure global decoherence rate*
11:40 – 12:00	Jeff Steinhauer:	*Realization of a sonic black hole analog in a Bose-Einstein condensate*
12:00 – 13:00	Lunch	
13:00 – 14:20	**3 session: Patent law, mesoscopic systems**	
	Location: Pyramida Hotel Lecture Hall	
13:00 – 13:20	William Blackman:	*International intellectual property issues of concern to scientists*
13:20 – 13:50	Yaroslav M. Blanter:	*Backaction and self-oscillations in nanomechanical systems*

13:50	–	14:20	Aashish Clerk:	*Full counting statistics of phonon and photon shot noise fluctuations*

14:20 – 15:20 **Round table**

Location: Pyramida Hotel Lecture Hall

15:20 – 15:30 **Closing address**

Location: Pyramida Hotel Lecture Hall

16:00 – 19:00 Guided tour through Prague

Public Lectures

Laser manipulation of atoms

Claude Cohen-Tannoudji

Collège de France and Laboratoire Kastler Brossel, Ecole Normale Supérieure, Paris, France

Understanding the nature of light and its interactions with matter has always been a challenge for Physics. New concepts have emerged from these investigations, such as the quantum nature of the microscopic world and the wave-particle duality. New mechanisms for the generation of light have also been discovered, leading to the realization of new light sources, called "lasers", with remarkable properties. The light emitted or absorbed by atoms is not only a valuable source of information on the structure of the world which surrounds us. It is also a powerful tool for acting on atoms, for manipulating them, for controlling their various degrees of freedom.

It will be shown how it is possible to use laser light for cooling atoms to very low temperatures, in the microkelvin, and even in the nanokelvin range. A few cooling mechanisms will be described. A review will be also given of recent developments in this field. A first one concerns ultra-precise atomic clocks using cold atoms, with errors less than one second in one billion years. These atomic clocks will allow one to perform more refined tests of fundamental theories, like general relativity, and to improve the global positioning system (GPS). Another spectacular application of ultracold atoms is the realization of new states of matter such as Bose-Einstein condensates, where a macroscopic number of bosonic atoms occupy the same wave function giving rise to a macroscopic matter wave. New perspectives opened by these results will be briefly discussed.

L2

From Big Bang to biospheres

Martin Rees

Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, United Kingdom

Astronomers have made astonishing progress in probing our cosmic environment, thanks to advanced technology. We can trace cosmic history back to some mysterious ‘beginning’ nearly 14 billion years ago, and understand in outline the emergence of atoms, galaxies, stars and planets – and how, on at least one planet, life developed a complex biosphere of which we are part. But these advances bring new questions into focus. How special is our Solar System? How widespread is life in our cosmos? Should we be surprised that the physical laws permitted the emergence of complexity, and what were the key stages in this emergence? And is physical reality even more extensive than the domain that our telescopes can probe? This illustrated lecture will address (but not answer!) such questions.

Invited Talks

MOA II gravitational microlensing survey

Fumio Abe

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If two different stars are almost perfectly aligned on the line of sight, apparent brightness of the background star is magnified by the gravitational lensing of the foreground star. This phenomenon named "gravitational microlensing" is predicted by Einstein in 1936. Since discovery of first event in 1993, microlensing phenomena have been used to search dark matter candidates (MACHOs), extrasolar planets, free-floating planets, etc. This phenomenon is also useful to study shape of the distant star.

MOA (Microlensing Observations in Astrophysics) project started in 1995 using 61 cm telescope in Mt. John Observatory, New Zealand. In 2003, we succeeded to find first planet using microlensing method. The MOA II 1.8 m telescope is installed in Mt. John in 2004 and started observation in 2005. Using large CCD camera MOA-Cam3, we have executed high-cadence observations toward Galactic bulge and Magellanic clouds. Until now, 11 extrasolar planets, 10 free-floating planets, and four MACHO candidates have been discovered.

In this talk, I will present MOA II gravitational microlensing survey and the results.

T2

Retrieving quantum qubit information despite decoherence

Amnon Aharony[1], Shmuel Gurvitz[2], Ora Entin-Wohlman[1], and Sushanta Dattagupta[3]

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[2] *Department of Particle Physics and Astrophysics, Weizmann Institute of Science, Rehovot 76100, Israel*

[3] *Indian Institute of Science Education and Research, Kolkata, Mohanpur 741252, India*

The time evolution of a qubit, consisting of two single-level quantum dots, is studied in the presence of telegraph noise. The dots are connected by two tunneling paths with an Aharonov-Bohm flux enclosed between them. Under special symmetry conditions, which can be achieved by tuning gate voltages, there develops partial decoherence: at long times, the off-diagonal element of the reduced density matrix (in the basis of the two dot states) approaches a nonzero value, generating a circulating current around the loop. The flux dependence of this current contains full information on the initial quantum state of the qubit, even at infinite time. Small deviations from this symmetry yield a very slow exponential decay toward the fully decoherent limit. However, the amplitudes of this decay also contain the full information on the initial qubit state, measurable either via the current or via the occupations of the qubit dots.

Bose-Einstein condensation, Casimir forces and quantum optics on fractal structures

Eric Akkermans[1], Gerald Dunne[2], and Alexander Teplyaev[2]

[1] *Department of Physics, Technion, Israel Institute of Technology, Technion, Haifa, Israel*

[2] *Physics and Mathematics, University of Connecticut, Storrs, USA*

Fractals define a new and interesting realm for a discussion of basic phenomena in QED and quantum optics and their implementation. This interest results from specific properties of fractals, e.g., their dilatation symmetry as opposed to the translation symmetry of Euclidean space and the corresponding absence of Fourier mode decomposition. Moreover, the existence of a set of distinct (usually non integer) dimensions characterizing the physical properties (spatial or spectral) of fractals make them a useful testing ground for dimensionality dependent physical problems.

We shall start by noting that the absence of Fourier transform on a fractal implies necessarily different notions of volume in direct and reciprocal spaces and thus the need to modify the Heisenberg uncertainty principle. Implications for field quantization and the definition of the notion of photon on a fractal will be further addressed.

These ideas will find interesting applications in quantum optics of fractal cavities. More specifically, we shall discuss the existence of a strong Purcell effect and of a modification of photon statistics as measured, e.g., in the Hanbury-Brown and Twiss setup.

We shall then turn to the case of massive bosons and discuss the nature of Bose-Einstein condensation and the onset of superfluidity in fractal structures. The existence of distinct fractal dimensions characterizing spatial and spectral properties is instrumental in understanding the dimensionality dependence of the BEC and the existence of a superfluid order either through the existence of an “Off Diagonal Long Range Order” (ODLRO) or the generalization of the Mermin-Wagner theorem on long range order and its implication on the existence of topological defects.

[1] E. Akkermans, G.V. Dunne and A. Teplyaev, Europhys. Lett. 88, 40007 (2009).

[2] E. Akkermans, G.V. Dunne and A. Teplyaev, Phys. Rev. Lett. 105, 230407 (2010).

[3] E. Akkermans and G.V. Dunne, Ramsey Fringes and Time-domain Multiple-Slit Interference from Vacuum, in preparation.

T4

The coexistence of superconductivity and ferromagnetism in nanoscale metallic grains

Yoram Alhassid

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A nano-scale metallic grain in which the single-particle dynamics are chaotic is a zero-dimensional system described by the so-called universal Hamiltonian. This Hamiltonian includes a superconducting pairing term and a ferromagnetic exchange term that compete with each other: pairing correlations favor minimal ground-state spin while the exchange interaction favors maximal spin polarization. Of particular interest is the fluctuation-dominated regime where the bulk pairing gap is comparable or smaller that the single-particle mean level spacing and the BCS theory of superconductivity breaks down. We find that superconductivity and ferromagnetism can coexist in this regime. Signatures of the competition between superconductivity and ferromagnetism are identified in a number of quantities:

Ground-state spin [1]. The coexistence regime is characterized by a ground state in which a number of electrons in the vicinity of the Fermi energy are polarized while all other electrons are paired. The coexistence region is characterized by jumps of more than one unit in the ground-state spin.

Conductance fluctuations [2]. The tunneling conductance through an almost-isolated grain that is connected to leads exhibits Coulomb blockade peaks as a function of a gate voltage. Pairing correlations leads to bimodality in the peak spacing distribution while exchange correlations suppress the conductance peak height fluctuations.

Thermodynamic properties and their mesoscopic fluctuations [3,4]. Pairing correlations lead to number-parity effects in the thermodynamic properties of the grain such as the heat capacity and spin susceptibility. The effects of spin exchange correlations differ qualitatively between the BCS and fluctuation-dominated regimes.

We have used two methods to calculate thermodynamic properties: (i) a quantum Monte Carlo method [3] and (ii) an approach in which exchange correlations are treated exactly using spin projection methods, while pairing correlations are treated in the static path approximation plus small amplitude time-dependent fluctuations around each static value of the pairing field [4]. Odd-even effects in the number of electrons are captured by a number-parity projection.

[1] S. Schmidt, Y. Alhassid, and K. Van Houcke, Europhys. Lett. 80, 47004 (2007).

[2] S. Schmidt and Y. Alhassid, Phys. Rev. Lett. 101, 207003 (2008).

[3] K. Van Houcke, Y. Alhassid, S. Schmidt, and S. Rombouts, arXiv: 1011.5421 (2010).

[4] K. Nesterov and Y. Alhassid, in preparation (2011).

Anderson transition in the cold atom kicked rotor

Alexander Altland

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I will discuss the first microscopic theory of transport in driven chaotic environments ('kicked rotors'), as realized in recent atom optic experiments. The behavior of these systems depends sensitively on the value of the dimensionless Planck constant $\tilde{h}$: for irrational values of $\tilde{h}/(4\pi)$ they fall into the universality class of disordered electronic systems and I will discuss the corresponding localization phenomena. In contrast, for rational values the rotor-Anderson insulator acquires an infinite (static) conductivity and turns into a 'super-metal'. This implies the existence a metal/super-metal quantum phase transition.

T6

Bound states in multilayers of cold polar molecules

Jeremy Amstrong, Nikolaj Zinner, Dmitri Fedorov, and Aksel Jensen

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The recent experimental realization of cold polar molecules in the rotational and vibrational ground state opens the door to the study of a wealth of phenomena involving long-range interactions. By applying an optical lattice to a gas of cold polar molecules one can create a layered system of planar traps. Due to the long-range dipole-dipole interaction one expects a rich structure of bound complexes in this geometry. We study the bilayer case and determine the two-body bound-state properties as a function of the interaction strength. The results clearly show that a least one bound state will always be present in the system. In addition, bound states at zero energy show universal behavior and extend to very large radii. Multi-layered systems are studied with a harmonic oscillator model and show interesting string structures. The stability of the structures is evaluated as a function of number of layers and density. Diverging amplitudes in the normal modes indicate that greater stability is achieved by removing particles from the outermost layers.

Nonequilibrium Zeeman-splitting in quantum transport through nanoscale junctions

Frithjof Anders and Sebastian Schmitt

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We present calculations of the nonequilibrium differential conductance G(V) through a quantum dot as function of bias voltage V and applied magnetic field H. We use a Keldysh conserving approximation for weakly correlated and the newly developed scattering states numerical renormalization group for the intermediate and strongly correlated regime out of equilibrium. In the weakly correlated regime, the Zeeman splitting observable in G(V) strongly depends on the asymmetry of the coupling to the two leads, as well as on particle-hole asymmetry of the quantum dot. In contrast, in the strongly correlated regime, where Kondo-correlations dominate, the position of the Zeeman-split zero-bias anomaly is independent of such asymmetries and always found to be of the order of the Zeeman energy. We will point out the importance of a crossover from the purely spin-fluctuation driven Kondo regime at small magnetic fields to a regime at large fields where the contribution of charge fluctuations induces larger splittings as it was observed in recent experiments.

T8

A new paradigm to describe mesoscopic systems by employing fractional exclusion statistics

Dragos Victor Anghel

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The concept of fractional exclusion statistics (FES) was introduced by Haldane in Ref. [1] and represents a generalization of the Pauli exclusion principle. The concept has been quite successful and has been applied to several types of systems, like anyons and quasiparticles in fractional quantum Hall systems, spin chains, Calogero-Sutherland model, etc.

In this talk I will show that some of the fundamental properties of the FES were missing from the general formalism and therefore the FES was inconsistent [2]. After that, I will introduce the general properties of FES [3], which extend the area of applicability of FES to practically any type of mesoscopic system [4,5,6] and provides a new paradigm for describing interacting particles as ideal particles with a more general type of statistics.

If the time will allow, in the end I will describe a method of calculating the transition rates and the time evolution of the particle distribution in nonequilibrium FES systems [7].

[1] F. D. M. Haldane, Phys. Rev. Lett. 67, 937 (1991).

[2] D. V. Anghel., J. Phys. A: Math. Theor. 40, F1013 (2007).

[3] D. V. Anghel, EPL 87, 60009 (2009).

[4] D. V. Anghel, Phys. Lett. A 372, 5745 (2008).

[5] D. V. Anghel, Rom. J. Phys. 54, 281 (2009).

[6] D. V. Anghel, EPL 90, 10006 (2010).

[7] G. A. Nemnes and D. V. Anghel, J. Stat. Mech. P09011 (2010).

Optimal control of open quantum systems in non-Markovian environments

Joachim Ankerhold[1], Jürgen Stockburger[1], Rebecca Schmidt[1], Antonio Negretti[2], and Tommaso Calarco[2]

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[2] *Institute for Quantum Information, University of Ulm, Albert-Einstein-Allee 11, 89069 Ulm, Germany*

The control of quantum dynamics for the accurate preparation of a prescribed quantum state by a tailored time-dependent field is a task of key importance in quantum physics and related disciplines. With increasing complexity of devices for quantum information processing the destructive role of environmental fluctuations has become a severe limitation to further progress.

Optimal control theory (OCT) has emerged as a key ingredient in strategies to tame the effect of decoherence and other imperfections either directly by mitigating their effect or indirectly by speeding up operations. However, so far OCT has treated environmental interactions mostly by heuristic or approximate methods, e.g. based on standard Markovian Master equations.

We present an approach for optimal control of open quantum systems based on formally exact stochastic Liouville-von Neumann equations [1,2]. This scheme is conceptually transparent and captures non-perturbatively the mutual impact of driving and dissipation. It reveals cooperative effects of driving and dissipation that can modify the open-system dynamics to the point where the entropy change turns negative, thus achieving cooling without any reliance on internal degrees of freedom [3].

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

[2] W. Koch, F. Grossmann, J.T. Stockburger, J. Ankerhold, Phys. Rev. Lett. 100, 230402 (2008).

[3] R. Schmidt, A. Negretti, J. Ankerhold, T. Calarco, J. T. Stockburger, arXiv:1010.0940

T10

Noise properties of cavity-driven mechanical oscillations

Andrew Armour

University of Nottingham, University Park, Nottingham, United Kingdom

Parametric coupling between a mechanical resonator and a driven optical or microwave cavity provides an effective way of suppressing thermal fluctuations in the mechanical resonator. When the cavity is driven below resonance, quanta are absorbed from the resonator by the cavity and the low level of photon noise in the cavity means that the mechanical resonator can in principle be cooled almost all the way to its ground state. However, when the cavity is instead driven above resonance energy is absorbed by the resonator. In this regime the resonator can undergo dynamical transitions to states of self-sustaining oscillation. Interestingly, the amplitude fluctuations in the resulting oscillating states are suppressed in the sense that they can be substantially less than in a corresponding state produced by simply applying a pure harmonic drive, the counterpart of the cooling that occurs in the stable regime.

How to extend quantum experiments to massive mechanical objects: Prospects and challenges

Markus Aspelmeyer

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In this talk I will discuss the recent developments in the field of quantum optomechanics. There the main idea is to use the framework of quantum optics in combination with radiation-pressure forces in an optical cavity to generate nonclassical states of motion of massive mechanical resonators. This opens up an avenue for new experiments to test the foundations of quantum physics in an unprecedented parameter regime of size and mass.

T12

Device independent witnesses for genuine multipartite entanglement

Jean-Daniel Bancal[1], Denis Rosset[1], Nicolas Gisin[1], Yeong-Cherng Liang[1], and Stefano Pironio[2]

[1] *GAP Optique, Université de Genève, Switzerland*

[2] *Laboratoire d'Information Quantique, Université Libre de Bruxelles, Belgium*

As experiments bring to light entangled states involving more and more particles, like up to six photons or fourteen ions [1,2], the need to certify that these states constitute a useful resource for practical purposes increases. In particular, one would like to show that entanglement shared between less particles cannot be used as a replacement for these states.

In a multipartite scenario involving n parties, a state is said to be genuinely n-partite entangled if it is not biseparable, i.e. if it cannot be produced by mixing states that are separable with respect to some partition. Several works have suggested ways of detecting such entanglement in experiments [3]. Typically these involve measurement of a witness of genuinely multipartite entanglement, or analysis of the state reconstructed from a full tomography.

Such approaches, however, require a detailed description of the observed systems and of the measurements performed in order to conclude the presence of multipartite entanglement. Indeed, one can easily violate an entanglement witness with a separable state if different measurement settings than the ones prescribed by the witness are used.

Here we consider the set of biseparable quantum correlations, which consists of all measurement statistics that can be observed by measuring an arbitrary biseparable quantum state [4]. In other words the production of non-biseparable quantum correlations constitutes a task which can only be achieved with the aid of genuinely multipartite entangled states. Since these correlations are defined independently of a specific Hilbert space dimension and of the precise nature of the measurements performed, we call inequalities satisfied by biseparable quantum correlations Device Independent Entanglement Witnesses (DIEWs).

DIEWs for two parties amount to Bell inequalites, i.e. witnesses of nonlocality. However for more parties, Bell inequalities are not necessarily witnesses of multipartite entanglement. Still we present a family of DIEWs that can be used in scenarios involving any number of parties. In addition to providing tests to detect multipartite entanglement which do not rely on the above assumptions, these inequalities shed some light on the relation between multipartite entanglement and multipartite nonlocality.

[1] T. Monz, et al., Phys. Rev. Lett. 106, 130506 (2011)

[2] W. Wieczorek, et al., Phys. Rev. Lett. 103, 020504 (2009).

[3] O. Guhne, and G. Toth, Physics Reports 474, 1 (2009).

[4] J.-D. Bancal, N. Gisin, Y.-C. Liang, and S. Pironio, arXiv:1102.0197.

Two-slit diffraction with highly charged particles: Niels Bohr's consistency argument that the electromagnetic field must be quantized

Gordon Baym

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This talk will present and analyze Niels Bohr's unpublished proposal of a two-slit interference experiment with highly charged particles that argues that the consistency of elementary quantum mechanics requires that the electromagnetic field must be quantized. In the experiment a particle's path through the slits is determined by measuring the Coulomb field that it produces at large distances; under these conditions the interference pattern must be suppressed. The key is that as the particle's trajectory is bent in diffraction by the slits it must radiate and the radiation must carry away phase information. Thus the radiation field must be a quantized dynamical degree of freedom. On the other hand, if one similarly tries to determine the path of a massive particle through an inferometer by measuring the Newtonian gravitational potential the particle produces, the interference pattern would have to be finer than the Planck length and thus undiscernable. Unlike for the electromagnetic field, Bohr's argument does not imply that the gravitational field must be quantized.

T14

Phases, broken symmetries, and Goldstone modes in helical magnets

Dietrich Belitz[1] and Ted Kirkpatrick[2]

[1] *University of Oregon, Department of Physics, Eugene, OR, USA*

[2] *University of Maryland, Department of Physics and Institute for Physical Science and Technology, College Park, MD, USA*

We review the phase diagram of helical magnets in the space spanned by temperature, magnetic field, and hydrostatic pressure as it is observed, e.g., in MnSi and FeGe. A hierarchy of energy scales leads to a variety of ordered phases, namely, a pinned helical phase, a conical phase, and the A-phase at intermediate magnetic fields and temperatures. We discuss the various broken symmetries in these phases and determine the resulting Goldstone modes. We also give an interpretation of the observed non-Fermi-liquid region in the paramagnetic phase at high pressure and argue that Goldstone modes exist in this regime as well.

Quasiprobability and quantum paradoxes in electronic counting statistics

Wolfgang Belzig[1] and Adam Bednorz[2]

[1] *University of Konstanz, Universitätsstr. 10, 78457 Konstanz, Germany*

[2] *Institute of Theoretical Physics, University of Warsaw, Warsaw, Poland*

The impossibility of measuring non-commuting quantum mechanical observables is one of the most fascinating consequences of the quantum mechanical postulates. Hence, to date the investigation of quantum measurement and projection is a fundamentally interesting topic. We propose to test the concept of weak measurement of non-commuting observables in mesoscopic transport experiments, using a quasiprobabilistic description. We derive an inequality for current correlators, which is satisfied by every classical probability but violated by high-frequency fourth-order cumulants in the quantum regime for experimentally feasible parameters. We further address the creation and detection of entanglement in solid-state electronics, which is of fundamental importance for quantum information processing. We propose a general test of entanglement based on the violation of a classically satisfied inequality for continuous variables by 4th or higher order quantum correlation functions.

To this end, we propose a derivation of the time-resolved full counting statistics of electronic current based on a positive-operator-valued measure [1]. Our approach justifies the Levitov-Lesovik formula in the long-time limit, but can be generalized to the detection of finite-frequency noise correlations. Since current operators at different times do not commute, the high-frequency correlation functions of the current are realization of this fundamental quantum question [2]. We formulate this problem in the context of measurements of finite-frequency current cumulants in a general quantum point contact, which are the subject to ongoing experimental effort. We then show that the unusual properties of weak measurements can be interpreted in terms of a real quasi- probability, which can take negative values [3]. Our interpretation agrees well with predictions and measurements of the current fluctuations in mesoscopic junctions. Finally, we propose a cumulant-based Bell test for mesoscopic junctions without the charge quantization assumption [4]. Therefore, we have constructed a classical inequality for non-local correlation measurements involving up to 4th order correlations. A spin-resolved quantum measurement on tunnel junctions violates this inequality in an experimentally accessible range of temperatures, voltages and time/frequency resolution.

[1] A. Bednorz and W. Belzig, Phys. Rev. Lett. 101, 206803 (2008).

[2] A. Bednorz and W. Belzig, Phys. Rev. B 81, 125112 (2010).

[3] A. Bednorz and W. Belzig, Phys. Rev. Lett. 105, 106803 (2010) .

[4] A. Bednorz and W. Belzig, Phys. Rev. B 83, 125304 (2011).

T16

International intellectual property issues of concern to scientists

William Blackman and Peter Keefe

Carrier, Blackman & Associates, 43440 West Ten Mile Rd, Novi, USA

Aspects of international patent, trademark and copyright practice of interest to scientists, including record keeping, first-to-file systems, Patent Cooperation Treaty, patent prosecution before the European Patent Office, differences between U.S. and European Trademark practice, free patent searching at espace.net, and professional searching services available from Nordic Patent Office.

Backaction and self-oscillations in nanomechanical systems

Yaroslav M. Blanter

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In any measurement, the detector influences the measured system. This effect, known as back-action, is unavoidable for a quantum measurement, but may have serious consequences even in the classical case. We will consider two specific examples of nanomechanical systems: a suspended beam in the single-electron tunneling regime and a suspended SQUID loop, and consider what is the effect of back-action in these devices. In the suspended beam, back-action induces dissipation which has been experimentally measured with carbon nanotubes. In a SQUID, the back-action shifts the frequency and affects the quality factor of the mechanical resonator. In a certain parameter range, the quality factor becomes negative, and the resonator self-oscillates. The theoretical results match the experimental data.

T18

Controlling and imaging quantum gases at the single atom level

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Over the past years, ultracold quantum gases in optical lattices have offered remarkable opportunities to investigate static and dynamic properties of strongly correlated bosonic or fermionic quantum many-body systems. In this talk I will show how it has recently not only become possible to image such quantum gases with single atom sensitivity and single site resolution, but also how it is now possible to coherently control single atoms on individual lattice sites within a strongly correlated quantum gas. Using a tightly focussed laser beam atoms on selected lattice sites can be addressed and their spin state fully controlled. Magnetic resonance control techniques were employed to achieve sub-lattice period and sub-diffraction limited resolution in our addressing scheme.

The ability to address single atoms on a lattice opens a whole range of novel research opportunities ranging from quantum information processing over the investigation of quantum spin systems to local entropy control, some of which will be discussed in the talk.

Strongly correlated few-fermion systems: From equilibrium properties to ultrafast dynamics

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In this talk I review some recent results for systems of few fermions. Examples include electrons in traps ("artificial atoms") and real atoms. I first discuss first-principle results for the thermodynamic properties based on path integral Monte Carlo simulations. These methods are hampered by the notorious fermion sign problem. We have recently developed a new approach which weakens this problem.

The second part of the talk is devoted to excitation of few-electron atoms by ultrashort UV laser pulses. Novel sources such as free electron lasers allow to trigger complex inter-atomic dynamics, including the dynamics of electronic correlations which we simulate by wave function based and nonequilibrium Greens functions methods.

T20

Towards quantum superpositions of a mirror

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Using a tiny mirror attached to a micromechanical resonator as one of the mirrors in an interferometer we aim to investigate macroscopic quantum superpositions. We analyze the effects of finite temperature on the proposed experiment and conclude that an unambiguous demonstration of a quantum superposition requires the mechanical resonator to be in or near the ground state. This can in principle be achieved by optical cooling of the fundamental mode, which also provides a method for measuring the mean phonon number in that mode. We also calculate the rate of environmentally induced decoherence and estimate the timescale for gravitational collapse mechanisms as proposed by Penrose and Diosi. We will show experimental data on optical cooling of an optical trampoline resonator starting from dilution refrigeration temperatures. Finally we discuss the technical challenges to be overcome in order to test quantum mechanics in the regime where gravitational effects might interfere.

Microcausality in quantum field theory

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Microcausality in quantum field theory in Minkowski spacetime is addressed in terms of a possible physical upper bound on proper acceleration relative to the vacuum, and the light cone and associated boundary of the causal domain are shown to be warped near the Planck scale. The canonical microcausality relation is modified to include dependence of the field on the four-velocity of the device measuring the field, so that the field commutation relation given by the two-point Pauli-Jordan function is replaced by a function concentrated near the Planck scale of spatial separation between the two devices measuring the field, or at much larger separation when the relative speed of the two measuring devices is near the canonical speed of light. A consequence is that the causal boundary, canonically defined by the light cone, is warped at these scales so that the timelike region extends into the canonical spacelike region. The speed of the associated causal connectivity can exceed the canonical measured speed of light. The condition for this warp-speed causal connectivity to occur maximally with instantaneous transmission is when the spatial component of the relative four-velocity of the two measuring devices is orthogonal to their spatial separation, and for spatial separations near the Planck scale. When the relative speed of the measuring devices is very large, the range for warp-speed causal connectivity may extend well beyond the Planck scale, but if the wavelength of the field excitation is much less than the range, the field is extremely reduced. It is also significant to stress that the modified quantum field is Lorentz invariant, and causal connectivity backward in time remains impossible.

T22

Quantum control of interacting qubits

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Quantum mechanics courses discuss how an initial state evolves if the Hamiltonian of the system is time-dependent. In quantum control, the question is reversed: how should the time-dependent Hamiltonian be chosen to achieve a prescribed time-dependence of the state of the system? After a general introduction, this talk will in particular address the problem of how many quantum bits of a quantum computer one needs to control to run an arbitrary quantum algorithm.

In the special case of linear arrays of qubits interacting by a Heisenberg oder anisotropic XXZ interaction, an arbitrary unitary transformation (i.e., quantum algorithm) can be generated by acting on one of the qubits at the end of the chain. In a recent theoretical study, we have determined the control sequences to implement a number of gates in small N-qubit systems (N=3 or 4) in a minimal time [1,2]. In the anisotropic case, the shortest gate times are achieved for values of the anisotropy parameter Δ larger than unity. To study the influence of possible imperfections in experimental realizations of qubit arrays, we analyze the robustness of the gate fidelities to random variations in the control-field amplitudes and finite rise times of the pulses. We also discuss applications of our results to arrays of superconducting qubits. Work done in collaboration with Rahel Heule (Basel), Daniel Burgarth (Imperial College London), and Vladimir M. Stojanovic (Basel).

[1] R. Heule, C. Bruder, D. Burgarth, and V.M. Stojanovic, Phys. Rev. A 82, 052333 (2010).

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Elastic light scattering from multi-level atoms: Ground-state quantum beats and evolution of coherence through quantum jumps

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Elastic light scattering from multi-level atoms is explored in a quantum jump approach. We focus our attention on a ground-state coherence that is both prepared and detected through spontaneous emission. Evolution of the coherence is recorded as a quantum beat [1] by the intensity correlation function of the light scattered into an optical cavity mode. We show that the anticipated decoherence due to background spontaneous emission is accompanied by an unanticipated coherent evolution: spontaneous-emission-induced quantum jumps contribute an additional stochastic component to the standard light shift, reversing the sign of the AC Stark effect. Our analysis extends recently reported work on "Decoherence due to Elastic Rayleigh Scattering" [2], and close parallels with quantum measurement paradigms may be drawn. We develop the parallels with quantum measurements and explore the consequences of stochastic light shifts for various atomic excitation schemes involving the elastic scattering of light.

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T24

Implications of radiative corrections for the particle-zeropoint field system: establishing contact with quantum electrodynamics

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In a previous work [1], quantum mechanics was derived by studying the problem of an otherwise classical particle – say an atomic electron – immersed in the stochastic zero-point field. Detailed balance was assumed to have been achieved between the power lost by the particle through radiation reaction and the power gained by it from the zero-point field. Considering that the background field had played its most important role by leading the system to this situation, the radiationless approximation – which is taken by neglecting terms that represent mere radiative corrections – then led to the Schrödinger equation, except for an undetermined parameter β proportional to Planck's constant, which entered as a measure of the intensity of the fluctuations induced by the zero-point field.

In this work we proceed to the determination of the value of β, by using explicitly the detailed-balance condition; the parameter is thus shown to have the universal value $\beta = \hbar/2$. This completes the derivation of the Schrödinger equation in the radiationless approximation.

Some major consequences of the radiative terms previously neglected are then investigated. Firstly, the specific contributions of both the background field and the radiation reaction to the rate of atomic transitions are calculated. The results reproduce exactly the quantum formulas for the Einstein A and B coefficients, assigning an unequivocal meaning to these formulas. Other important radiative corrections, such as the shift of the atomic levels and the accompanying mass correction due to the residual effects of the zero-point field and radiation reaction, are shown to also be given by our equations. The theory allows thus to recover results that are usually considered to pertain to the specific province of quantum electrodynamics.

[1] L. de la Pena, A. M. Cetto and A. Valdés-Hernández, abstract submitted to this conference.

Statistical mechanics of magnetic impurities on graphene

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Localized impurities randomly positioned on the surface of a two-dimensional graphene are shown to exhibit a non-analytic dependence on 1/T at high temperature. This effect is caused by the non-integrable short-distance singularity of the electron-mediated RKKY exchange between the localized spins resulting in the failure of the usual high-temperature expansion. A modification of the high temperature expansion resolving the short-distance problem is proposed and the large-temperature susceptibility of the system is calculated. The results are used to investigate the critical properties of the system near the magnetic ordering transitions at intermediate temperatures.

T26

Generation of gravitational radiation via superluminal quantum mass currents

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The generation of power in gravitational radiation goes up as the sixth power of the velocity of sound in the material used in a Weber bar. Since the velocity of sound is a measure of the rigidity of a material, this indicates that the search for efficient generators and detectors of gravitational radiation at high frequencies is the search for an unusually rigid material. We have identified such a material with an unusual quantum-mechanical rigidity, which originates in the rigidity of the wavefunction of superconductors, namely, a superconducting wire clad with copper. We shall present preliminary data from experiments in which longitudinal microwave signals are propagated down such wires to measure their rigidity.

Full counting statistics of phonon and photon shot noise fluctuations

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Recent advances in both circuit QED and quantum optomechanics have made it possible to make QND measurements of the low-frequency energy fluctuations of a driven quantum resonator. In a previous study [1], we demonstrated that the higher moments of these fluctuations are surprisingly non-classical: the low-temperature, quantum expression is not equivalent to the high-temperature classical expression evaluated at some effective temperature. In this talk, I will discuss more recent work looking at the full probability distribution of these fluctuations. Surprisingly, the distribution can fail to be positive definite, similar to charge counting statistics in superconducting systems. I will discuss how these effects represent a new way to detect non-classical behaviour.

[1] A. A. Clerk, F. Marquardt, and J. G. E. Harris, Phys. Rev. Lett. 104, 213603 (2010).

T28

Quantum vs stochastic non-equilibrium steady state of driven systems

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A resistor-network picture of transitions is appropriate for the study of energy absorption by weakly chaotic or weakly interacting driven systems. Such "sparse" systems reach a novel non-equilibrium steady state (NESS) once coupled to a bath [1].

In the stochastic case there is an analogy to the physics of percolating glassy systems, and an extension of the fluctuation-dissipation phenomenology is proposed.

In the mesoscopic case the quantum NESS might differ enormously from the stochastic NESS, with saturation temperature determined by the sparsity.

The theory might apply to the analysis of energy absorption by Billiards with vibrating boundaries [2,3]. If the billiard were strongly chaotic, and the collisions with the walls were regarded as uncorrelated, the rate of heating would be determined by the "Wall formula", which is analogous to the "Drude formula" in the theory of electrical conductance.

[1] D. Hurowitz and D. Cohen, Europhys. Lett. 93, 60002 (2011).

[2] A. Stotland, D. Cohen, and N. Davidson, Europhys. Lett. 86, 10004 (2009).

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Advancing quantum transport for nuclear reactions

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We report progress on developing quantum transport theory for central nuclear reactions, based on nonequilibrium Green's functions. The challenge in advancing that theory is in handling the enormous amount of information within the Green's functions that are matrices in the pairs of space and time arguments. In the semiclassical limit, one finds that those arguments represent the momentum and energy content of a system at a given position and time. Simple estimates show that blind attempts to discretize the Green's function arguments are going to overwhelm computer capabilities in the foreseeable future. A more peripheral issue before the theory is that of preparation of the initial state in a manner that is consistent with the approach for the collisions. With the goal of tackling the above issues, we investigate a system of slabs colliding in one dimension within the mean-field approximation. While this system poses no computational obstacles of any kind, it allows to test strategies for realistic reaction simulations. With regard to the initial state, we find that we can prepare a state consistent with the collision evolution by adiabatically converting the hamiltonian, from one for which we know the solutions, to the interacting one. Regarding the matrix structure, we find that only elements next to the diagonal in the spatial representation matter in practice for reaction evolution. When we artificially remove elements away from the diagonal in the matrix description of a reaction, we find from nearly no effect to very little onto the progress of a reaction, depending how aggressively we suppress the elements. The insensitivity to the far-away elements can be associated with the late-term expansion of the reacting system, that causes any structures within the matrix arguments to move away from the diagonal of the matrix but hardly ever back to the diagonal. Dropping of the far-away elements amounts to a momentum-space coarse-graining of the functions within their Wigner representation. The findings bode well for the possibility of carrying out realistic reaction simulations, particularly in that the information that needs to be followed in those simulations can be tamed.

T30

Quantum nonlocality revisited from the point of view of a local stochastic theory

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Nonlocality continues to pose some of the major conceptual difficulties for quantum mechanics. In the present work, we revisit quantum nonlocality by studying the problem of an otherwise classical particle immersed in a stochastic radiation field that includes the zero-point contribution. The corresponding stochastic Liouville equation in the phase space of the complete (particle+field) system is first reduced to a Fokker-Planck-type equation for the particle phase-space density $Q(x, p, t)$. In the transition to configuration space, which implies a partial averaging, an infinite hierarchy of equations is obtained for the particle; the first is the continuity equation for $\rho(x, t) = \int Q(x, p, t)dp$ and the second one is the equation for the transfer of momentum $\langle p \rangle(x)$, which contains in addition the higher-order moments $\langle p^n \rangle(x)$, coupling it to the rest of the hierarchy.

At this stage, the system is assumed to have reached a situation of detailed balance between the power lost by the particle through radiation reaction and the power gained by it from the zero-point field. The background field has played by then its most important role by leading the system to this situation, and one can therefore neglect the terms that represent mere radiative corrections to a first approximation. This leads to a decoupling of the first two equations from the rest of the hierarchy. The statistical information of the mechanical system is thus completely contained in the continuity equation plus an equation for the particle flux, which has an entirely classical shape except for an extra nonlocal term due to the fluctuations of the momentum (induced by the zero-point field). This nonlocal contribution is shown to be fully equivalent to the so-called quantum potential.

The couple of equations derived is recast, through simple mathematical transformations, into Schrödinger's equation and its complex conjugate, except for the value of Planck's constant which is determined in a separate paper [1]. The nonlocal information characteristic of the solutions of the Schrödinger equation is thus traced to the dynamics of the particle in momentum space, resulting from the fluctuations of the zero-point field. Nonlocality and quantum fluctuations emerge therefore as distinctive features of the quantum description, rather than being inherent properties of the system. Further, the theory is shown to allow, in principle, for a natural extension of the quantum description in phase space that is fully Kolmogorovian.

[1] A. M. Cetto and L. de la Pena, abstract submitted to this conference.

Towards a corpuscular event-by-event simulation of optical phenomena

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A corpuscular simulation model of optical phenomena that does not require the knowledge of the solution of a wave equation of the whole system and reproduces the results of Maxwell's and quantum theory by generating detection events one-by-one is presented. The event-based corpuscular model is shown to give a unified description of multiple-beam fringes of a plane parallel plate, single-photon Mach-Zehnder interferometer, Wheeler's delayed choice, photon tunneling, quantum eraser, two-beam interference, double-slit, Einstein-Podolsky-Rosen-Bohm and Hanbury Brown-Twiss experiments.

T32

Continuous limit of discrete time quantum walks

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We consider discrete time quantum walks describing a particle jumping to the right or to the left in discrete one-dimensional infinite space. These walks are described by a coin operator acting on a two dimensional Hilbert space and the dynamics of each walk is specified by a possibly time-and space-dependent SU(2) operator i.e. by three, possibly time- and space-dependent angles.

We prove that all these discrete walks admit formal continuous limits. In the continuous limit, the two components of the wave-function obey a system of two, very simple coupled first order PDEs. These PDEs imply that each component of the wave function also obeys, in the continuous limit, an autonomous Klein-Gordon like, thus second order, equation. The first order system and the second order Klein-Gordon like equations all derive from variational principles. These make clear that each walk preserves certain symmetries, but breaks other ones. The variational principles also suggest a new interpretation of the three angles defining each walk.

Phase diagram of the integrable px+ipy fermionic superfluid

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The exact solution of the SU(2) pairing Hamiltonian with non-degenerate single particle orbits was introduced by Richardson in the early sixties, although largely forgotten till the last decade when is was rediscovered in an effort to describe the disappearance of superconductivity in ultrasmall grains. Since then Richardson's exact solution has been generalized to several families of exactly solvable Richardson-Gaudin models [1]. However, only rational family has been widely applied to mesoscopic systems where finite size effects play an important role. We have recently found an implementation of the hyperbolic family of the Richardson-Gaudin models to describe p-wave pairing [2]. Using this new tool we study the quantum phase diagram of a spinless Fermi gas in a 2D optical lattice with $p_x + ip_y$ pairing symmetry. Unlike the case of s-wave pairing, which has a smooth a crossover between BCS and BEC, p-wave pairing displays a quantum phase transition separating two gapped superfluid phases known as weak-pairing and strong-pairing. We make use of the exact solution for finite systems as well as mean-field BCS, which we show to be exact in the thermodynamic limit, to characterize the quantum phase transition and the properties of the two phases. As in the case of the BCS-BEC crossover of s-wave pairing [3], the exact wavefunction of the p-wave pairing Hamiltonian gives a beautiful insight into the nature of the quantum phase transition as well as into the structure of the Cooper pairs in the different phases. Moreover, it suggests the existence of an experimentally accessible characteristic length scale, associated with the size of the Cooper pairs, that diverges at the transition point, indicating that the phase transition is of a confinement-deconfinement type without local order parameter.

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T34

Relaxation, thermalization, and a quantum algorithm to prepare Gibbs states

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This talk will be concerned with recent progress on understanding how quantum many-body systems out of equilibrium eventually come to rest. The first part of the talk will highlight theoretical progress on this question - employing ideas of Lieb-Robinson bounds, quantum central limit theorems and of concentration of measure [1-4]. These findings will be complemented by experimental work with ultra-cold atoms in optical lattices, constituting a dynamical 'quantum simulator', allowing to probe physical questions that are presently out of reach even for state-of-the-art numerical techniques based on matrix-product states [5]. The last part of the talk will sketch how based on the above ideas, a fully certifiable quantum algorithm preparing Gibbs states can be constructed, complementing quantum Metropolis algorithms [6].

(*Joint work with C. Gogolin, M. Mueller, T.J. Osborne, A. Flesch, M. Cramer, U. Schollwoeck, I. Bloch, S. Trotzky, Y.A. Chen, A. Riera.*)

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[6] Gibbs states, exact thermalization of quantum systems and a certifiable algorithm for preparing thermal states, submitted to Phys. Rev. Lett. (2011).

Spin-polarized electric currents in quantum transport

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We review briefly the relation of spin-orbit coupling and topological insulators, and the origins of spin-orbit interactions in semiconductors. We then discuss the experimental observation of spin- polarized electric currents in quantum wires placed in a magnetic field. Then we describe our contribution: the observation of spin-polarized electric currents in the absence of magnetic fields [1]. To this end, we begin by outlining the derivation of a Landauer-type formula for the spin and the charge currents, through a finite region where spin-orbit interactions are effective. It is shown that the transmission matrix yields the spatial direction and the magnitude of the spin polarization. This formula is used to study the currents through a tubular two-dimensional electron gas. In this cylindrical geometry, which may be realized in experiment, the transverse conduction channels are not mixed (provided that the spin-orbit coupling is uniform). It is then found that for modest boundary scattering, each step in the quantized conductance is split into two, and the new steps have a non-zero spin conductance, with the spin polarization perpendicular to the direction of the current.

[1] O. Entin-Wohlman, A. Aharony, Y. Tokura, and Y. Avishai, Phys. Rev. B 81, 075439 (2010).

T36

Thermodynamics of quantum measurements

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Quantum measurement of a system can change its mean energy, as well as entropy, thus disturbing thermal equilibrium and allowing for work to be extracted. A selective measurement (classical or quantum) can be used as a “Maxwell’s demon” to power a single-temperature heat engine (e.g., a Szilard engine), by decreasing the entropy. Quantum mechanically, so can a non-selective measurement, despite increasing the entropy of a thermal state. The maximal amount of work extractable following the measurement is given by the change in free energy: $W=\Delta E-T_{Bath}\Delta S$, where ΔE and ΔS are the changes in the mean energy and the entropy, respectively, due to the measurement. I show that the extractable work in the case of a selective measurement exceeds that of the non-selective measurement by exactly the amount of work needed to reset the memory of the measuring device (“demon”), and furthermore no such resetting is needed in the non-selective case! Consequently, a single-bath engine powered by either kind of measurement works at the same net loss of $T_{Bath}\Delta S_{nonsel.}$ per cycle. By replacing the measurement by a reversible “premeasurement” and allowing a work source to couple to the system and memory, the cycle can be made completely reversible.

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Quantum coherence in nanofabricated three-level artificial atoms

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The dynamics of three-level superpositions are clear demonstrations of situations in which quantum coherence plays the central role, leading to novel phenomena wherein quantum effects manifest in unexpected way [1]. In this perspective it has been proposed to study multilevel coherent effects in superconducting nanodevices [2], where very recently, few experiments have demonstrated features of multilevel coherence [3].

Superconducting nanocircuits are easily addressable and flexibile in the design, but they are sensitive to broadband noise. Protection was successfully achieved in two-state devices by tuning at symmetry points, where however parity selection rules prevent for most of the devices in [3] to implement the usual Lambda scheme widely employed in Quantum Optics.

We study broad band noise in a three-level system Lambda-scheme during a stimulated Raman adiabatic passage (STIRAP) protocol [1]. The main mechanism of efficiency loss is dephasing of the first energy doublet due to low frequency fluctuations. They spoil completely the adiabatic evolution, but efficient population transfer is still possible via Zener tunneling. We analize qutrits in the Cooper-pair box design, where noise-protection is modulated with fabrication parameters. Counterintuitively best performing qubits turn out to be not useful for such protocols, STIRAP being only possible in the so called charge-phase regime.

We finally show how design of correlations between energy levels fluctuations may allow to overcome the limitation imposed by selection rules. This scheme is applicable to phase qubits, showing the importance of nanodevice band-structure engineering for multilevel coherent control.

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[3] M.A. Sillanpää et al., Phys. Rev. Lett. 103 (2009) 193601; M. Baur et al., Phys. Rev. Lett. 102 (2009) 243602; W.R. Kelly et al., Phys. Rev. Lett. 104 (2010) 163601.

T38

Quantum and semiclassical noiseless amplifier

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We report about two basic novel probabilistic measurement-induced amplifiers working without any phase reference [1] and their recent experimental tests [2,3]. The amplification schemes use two qualitatively different resorces: either single photon addition (quantum amplifier) or thermal noise addition (semiclassical amplifier), both followed by feasible multiple photon subtraction using realistic photon-number resolving detector. Both of them allow to substantially amplify weak coherent states and simultaneously reduce their phase uncertainty, contrary to the deterministic quantum amplifier, even without any internal or external phase reference. A distiction between the quantum amplifier and the semiclassical amplifier and their potential applications will be described.

[1] P. Marek and R. Filip, Phys. Rev. A 81, 022302 (2010)

[2] M.A. Usuga et al., Nature Physics 6, 767 (2010)

[3] A. Zavatta et al., Nature Photonics 5, 52 (2011)

Emergence of non-thermal statistics in isolated many-particle quantum systems after multiple perturbations

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We investigate what ensembles emerge dynamically in the course of strictly unitary manipulations of quantum systems. In particular, we look at the effects of multiple small non-adiabatic perturbations. This investigation is motivated by the following concerns. On the one hand, a typical quantum state of a large system constitutes a superposition of eigenstates that do not necessarily fall into the microcanonical energy window or represent any other conventional ensemble consistent with the Gibbs equilibrium for small subsystems. On the other hand, the linearity of quantum mechanics implies that the occupations of quantum eigenstates of isolated systems do not change with time. Therefore, if the statistical ensemble that emerges as a result of a given preparation routine is inconsistent with the requirements for the Gibbs equilibrium, then the system considered will never thermalize on it own. That the above concerns are not purely abstract is demonstrated by our recent work showing that, on the one hand, a certain natural ensemble called "Quantum Micro-Canonical" (QMC) ensemble leads to a non-thermal statistics[1], while, on the other hand, very similar ensembles were generated numerically by multiple small non-adiabatic perturbations acting of isolated clusters of spins 1/2 in a rather generic setting[2]. The QMC ensemble is defined for large but finite Hilbert spaces and admits all possible quantum superpositions with a given energy expectation value. In comparison with the conventional canonical ensemble, the QMC ensemble implies higher occupations for both very low- and very high-energy states and, correspondingly, lower occupations for the intermediate-energy states[1]. In our numerical investigations, we perturbed finite clusters of anisotropically coupled spins 1/2 by sudden pulses of external magnetic field[2]. Various sequences of magnetic field pulses were tried. In each run, a spin cluster was initially in a conventional thermal equilibrium. We have found that strictly periodic pulses lead to the dynamical localization of energy and the resulting the freezing of the time evolution of quantum ensembles. However a small randomization of the time delay between the pulses suppressed the above localization, and as a result the numerically generated statistical ensembles gradually departed from the canonical statistics and approached the QMC-like statistics. A possible implication of the above results is that isolated quantum systems having not too large number of particles but already large number of quantum levels might universally exhibit the non-thermal QMC-like statistics under multiple small perturbations. The implications of these results for macroscopic systems require further study.

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T40

Evidence for spatial variation of the fine structure constant

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I present a review of recent works devoted to the space-time variation of the fine structure constant alpha, strong interaction and fundamental masses. New results based on the quasar absorption spectra provide evidence for the variation of the fine structure constant alpha in space. The results for the direction and magnitude of the alpha gradient obtained using data from different telescopes are in agreement. Also, there are no contradictions with the results of different groups. The spatial variation can explain fine tuning of the fundamental constants which allows humans (and any life) to appear. We appeared in the area of the Universe where the values of the fundamental constants are consistent with our existence. The space-time variation of the fundamental constants is suggested by theories unifying gravity with other interactions. These astrophysical results may be used to predict the variation effects for atomic clocks where very accurate measurements have been performed recently. I also describe recent theoretical and experimental works on the nuclear clock based on the narrow UV (7 eV) transition between the ground and first excited states in 229Th nucleus. The effect of the fundamental constant variation in this transition may exceed the effects in atoms by several orders of magnitude. There are also enhanced effects in a number of atoms, ions and molecules.

Phonon damping and renormalization of Rabi oscillations in InGaAs quantum dots

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Optically-driven Rabi rotations of a neutral exciton in a single InGaAs quantum dot have been studied between 5 and 50 K for pulse areas of up to 14π. The Rabi oscillations exhibit intensity damping with a temperature dependence that is in close quantitative agreement with an acoustic-phonon model [1]. In the high driving field regime, the period of the Rabi rotations decreases with pulse area and increases with temperature. By comparing the experiments to a weak-coupling model of the exciton-phonon interaction, we demonstrate that the observed renormalization of the Rabi frequency is induced by fluctuations in the bath of longitudinal acoustic phonons, an effect that is a phonon analogy of the Lamb shift [2].

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T42

Quasielastic spectra in the Mössbauer effect and neutron scattering

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In proteins the Mössbauer effect and neutron scattering show a rapid increase of the mean-square-displacement (msd) above about 180 K. The increase is accompanied by the appearance of a broad band. The standard explanation of the increase, dubbed "dynamical transition", is controversial and no satisfactory explanation for the broad band has been put forward. We introduce a new interpretation of the Mössbauer effect in proteins. We prove that there is no dynamical transition and that the separation into a sharp line and a broad band is misleading. The broad band is inhomogeneous and is composed of sharp Mössbauer lines that have been shifted by βh fluctuations in the protein's hydration shell and α fluctuations in the bulk solvent. In the crystals used for the Mössbauer experiments the α fluctuations are absent. Using the dielectric spectrum of the βh fluctuations, we predict the shape of the Mössbauer spectrum from 80 K to 295 K with one dimensionless coefficient. The explanation is important for the dynamics of proteins and for the interpretation of quasielastic neutron scattering in complex systems.

Theory of time-resolved photoemission spectroscopy

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In this talk, I will present a brief summary of the nonequilibrium many-body formalism for time-resolved (pump/probe) photoemission spectroscopy [1,2]. This formalism uses a straightforward evolution of the system along the Kadanoff-Baym-Keldysh contour with contour-ordered Green's functions which can be calculated exactly using dynamical mean-field theory. The photoemission spectra results from a two-time Fourier transform of the lesser Green's function, appropriately weighted by the probe pulse profile. I will next give examples of how one can use this technique to either see the evolution of the density of states from equilibrium to nonequilibrium (when driven by a constant pump) [3] or to see how the system evolves when driven by a pump and allowed to relax via many-body interactions (but no reservoir) [4]. In this latter case, one can see how the hot electron model is a good, but not perfect approximation. If time allows, I will also present results for what happens in a driven charge-density-wave phase at zero temperature (which has no relaxation processes), where the response after the pump cannot be easily described by a simple hot electron model. This latter effect arises from the fact that the order parameter can oscillate in time, yielding an oscillatory current in the "steady state". For photoemission, we see a decoupling of the phenomena of gap closure versus vanishing of the order parameter, hence the "melting" of a charge-density-wave insulator is more complicated in nonequilibrium situations than it is in equilibrium.

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T44

Quantum friction and quantum Brownian motion

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I discuss recent results - obtained in collaboration with W. De Roeck, A. Pizzo, K. Schnelli, Gang Zhou and others - on the phenomena of friction by emission of Cerenkov radiation and diffusion of a quantum tracer particle coupled to a dispersive quantum-mechanical medium/reservoir. The models considered in our work are fully quantum-mechanical. The effective dynamics of the tracer particle is derived by systematically eliminating the degrees of freedom of the reservoir.

Raman spectroscopy of molecular junctions

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Recent advances in experimental techniques at nanoscale, and in particular Raman scattering measurements on current-carrying single molecule junctions promises to become a superior diagnostic tool. Theoretical understanding of optical response of open molecular systems far from equilibrium is of major importance for development of molecular optoelectronic devices. Within simple models we consider intra-molecular and charge-transfer contributions to Raman spectroscopy of molecular junction. Also we discuss a concept of "effective temperature", its relevance in representation of bias-induced heating, and ability of Raman measurements to provide information on the latter.

T46

Hydro-gravitational-dynamics of the cosmological big bang and the biological big bang

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From the hydrogravitational cosmology HGD [1,2], primordial hydrogen and helium-4 gas planets in million-star-mass clumps fragment at the plasma to gas transition 300,000 years after the cosmological big bang, forming the missing mass of galaxies. Thirty million Earth-mass frozen-gas-planets (micro-brown-dwarfs μBD) exist per star in a galaxy from HGD, not 8-10 as usually assumed. All stars come from mergers of these planets within their clumps. Mergers are by frictional accretion, first forming larger planets and finally stars. The clumps are termed proto-globular-star-clusters, or PGCs, since globular-star-clusters result when the supply of planets is exhausted.

HGD cosmology renders ΛCDMHC cosmology obsolete. The cosmological constant Λ is not needed to supply anti-gravitational forces of the big bang, since these arise from large but temporary turbulence and gluon-viscosity negative stresses of inflation [3]. Observations of Λ from supernovae 1a are systematic dimming errors from evaporated μBD near carbon stars over-fed by planets. Photon-viscous fragmentation of the plasma epoch begins at 30,000 years after the big bang to form proto-supercluster-voids, proto-cluster-voids and finally proto-galaxy voids at the plasma-gas transition. Cold-dark-matter CDM and hierarchical clustering HC to form CDM halos are misleading, unnecessary, and meaningless concepts that are replaced by HGD cosmology [4].

First stars, first supernovae, first chemicals C,N,O,P,Si,Fe and first life result from HGD cosmology soon after the plasma to gas transition. The first water oceans form on the 10^{80} planets of the big bang at 2 million years when the temperature of the universe matches the critical temperature of water 647 K. Comets and other fragments of planet mergers should transmit information widely among the planets and galaxies about efficient mechanisms of auto-catalytic self-replicating carbon-based reactions (life) in this promordial cosmic soup kitchen, vindicating the Fred Hoyle and Chandra Wickramasinghe concepts about cometary panspermia. The water oceans freeze at 8 million years when the universe temperature cools to 273 K, ending the biological big bang but not evolution [4].

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Observation of 'neutral modes' in the QHE regime via shot noise measurements

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Current propagates in the quantum Hall regime along the edges of a two-dimensional-electron gas via chiral edge modes, with chirality dictated by the applied magnetic field. In the fractional regime, for some fractional states - the so called 'holes-conjugate' states – e.g., between filling factor 1/2 and 1 - early predictions suggested the presence of counter propagating charge modes: a 'downstream' mode with the expected chirality and an 'upstream' mode with an opposite chirality. Since experiments in the (ubiquitous) 2/3 fractional state did not find an upstream propagating edge mode, it was theorized that in the presence of interactions and disorder edge reconstruction may take place with a resultant downstream charge mode accompanied by an upstream 'neutral mode' - with the latter carrying only energy. This explained why upstream charge modes were not detected previously, while neutral modes are more difficult to detect. More recently, neutral modes were predicted to exist in a variety of cases. For example, they are expected to be found when multiple edge modes (such as in filling factor 2 or higher for electrons, or for composite fermions) interact. Alternatively, neutral Majorana modes, which are expected to exist for a few proposed wavefunctions of the non abelian state 5/2, are crucial for the identification of the state.

We will present some of our observations of neutral modes in a few selected quantum Hall states. Neutral mode detection was performed by allowing the chiral neutral mode (being 'downstream' or 'upstream') to impinge on a quantum point contact constriction. Partitioning of the neutral mode led to current fluctuations (with a zero average current) propagating towards the amplifier. We will present some of the characteristics of the observed neutral modes in the integer and fractional regimes of the quantum Hall effect, and show a dual behavior with charge modes.

T48

Circuit approach to photonic heat transport

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We discuss the heat transfer by photons between two metals coupled by a circuit containing linear reactive impedances. Using a simple circuit approach we calculate the spectral power transmitted from one metal to the other and find that it is determined by a photon transmission coefficient which depends on the impedances of the metals and of the coupling circuit. We study the total photonic power flow for different coupling impedances both in the linear regime where the temperature difference between the metals is small and in the nonlinear regime of large temperature differences.

Hidden assumptions in proofs of Bell

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John Bell's inequalities are often considered to be a cornerstone of interpretations of quantum mechanics. It is shown in this presentation that Bell's inequalities were already explained by Boole's probability theory of 1862, when he established a one to one correspondence between experimental outcomes and mathematical abstractions; two-valued functions that permit the logical operations AND OR and NOT. We now regard these functions as elements of a Boolean algebra. Violation of the inequalities indicated to Boole an inconsistency and the necessity to revise the set of mathematical abstractions that follow the rules of the algebra.

Bell and his followers derived their inequalities for two valued functions unaware of Boole's work. They attempted to link a violation of these inequalities to violations of some of Bell's assumptions regarding physical reality. It will be demonstrated that Bell's work contained also hidden assumptions, not demanded by physical law. These hidden assumptions prevented an appropriate revision of the algebra referred to by Boole. In the language of modern probability theory, Bell did not introduce general functions on the most general and appropriate sigma-algebra. These functions would have obeyed different, physically and mathematically reasonable, inequalities.

The appropriate generalization of Bell's work involves two steps. Mathematically speaking one must search for sigma-algebras, and functions on them, that remove the troublesome topological-combinatorial "cyclicities" used by Bell. Vorob'ev's work, performed 100 years after Boole and contemporary with Bell, shows how this can be done. Second, on the side of physics, and for the case of Einstein-Podolsky-Rosen (EPR) type of experiments, a possibility of space-time dependencies of preparation and/or measurement of the particles need be introduced. We will discuss such space-time dependencies based on interactions of the equipment with the environment as well as based on many body effects.

In addition to revising Bell's inequalities, our general mathematical and physical treatment permits also to assess the validity of concepts created or applied by Bell and his followers including "outcome independence" and "counterfactual reasoning". We show that Einstein local sigma-algebras and vector stochastic processes on these algebras violate outcome independence and render counterfactual reasoning irrelevant. Claims that Bell's theorem proves influences at a distance are, therefore, incorrect.

T50

Slow relaxation and aging in the electron glass

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(Based on work with Ariel Amir and Yuval Oreg)

The phenomena of slow relaxation and "aging" in glasses, with emphasis on electronic ones, will be briefly reviewed. It will be shown that a spectrum of relaxation rates, λ, behaving approximately as $1/\lambda$ (for small λ) can explain these effects, while producing a universal description in terms of a simple function. We find that this description holds also for other glasses and for different physical properties.

We obtained this spectrum before, based on approximations for the hopping model. Now we shall consider the related random "distance" matrices model, where the matrix elements depend exponentially on the distance between uniformly and randomly distributed points. This model arises naturally in various further physical contexts, such as the diffusion of particles, and scalar phonon localization. Using a combination of a renormalization group procedure and a direct moment calculation, we find the exact eigenvalue distribution and the localization properties of the eigenmodes, at low densities, for **arbitrary dimension**. The results agree perfectly with numerics. Finally, we discuss the physical implications of the results vis a vis the universal relaxation mentioned above. We shall show that much of the relevant Physics is captured by this model.

Heat conduction in nanostructured graphene

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Graphene is an excellent heat conductor, and its application as a thermoelectric material - as we propose here - may sound foolhardy. Specifically, the thermoelectric figure of merit, ZT, is proportional to electrical conductivity σ and inversly proportional to heat conductance κ. (κ has both an electronic and phononic component where the latter is usually dominant.) For an optimal ZT one needs to maximize σ and minimize κ, which is very difficult for naturally occuring materials. Another challenge with graphene is that the Dirac nature of the charge carriers makes them difficult to control and confine by barriers, because of Klein tunneling. During last three years our group has been promoting the idea of an antidot lattice fabricated on graphene: this will create a band-gap and therfore allow control of charge flow. Recent advances in device fabrication have made the nanometer scale antidot lattices a reality, and we expect to see further improvements in near future. Here, we demonstrate theoretically that a suitably designed antidot lattice can block the phonons, yet allow charge flow, thereby moving an important step towards the ultimate goal of optimized thermoelectric design. Our theory is based on ab initio quantum transport calculations, where the electrons and phonons are treated on equal footing, and nonequilibrium Green's functions are used to evaluate the conductances. We complement the quantum transport simulations with Molecular Dynamics simulations, to account for anharmonic interactions.

T52

Precision measurements and weak values

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Weak values of quantum operators occur when quantum measurements are both pre- and post-selected. They are characterized by the peculiar features of both being complex and exceeding the eigenvalue bound of the operator. We show how this quantity may be described in a theoretically consistent way by defining contextual values as a generalization of the eigenvalues of an observable that takes into account both the system observable and a general measurement procedure. We further present experiments in optical systems showing how weak values may be used as a novel amplification scheme for precision measurements.

Relaxation phenomena in the adiabatic phase transition of Type I superconductor particles

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The first order phase transition of a Type I superconductor involves thermal and electrodynamic relaxation processes of the control variables for which the time of the electrodynamic relaxation is three orders of magnitude faster than the thermal relaxation. [1] In the first order adiabatic phase transition of macroscopic specimens, collective averaging renders relaxation time differences of the control variables unobservable and the phase transition isentropic. In the first order adiabatic phase transition of mesoscopic particles, coherence renders time differences of the control variables observable and, with profound consequence, the phase transition non-isentropic. [2-5] In addition to a theoretical discussion, presented are particulars of how the relaxation processes of the control variables for first order adiabatic phase transitions in both the macroscopic and mesoscopic size regimes will be experimentally investigated in the near future utilizing techniques developed by S.V. Dubonos. [6]

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T54

QM as theory of classical signals with noisy background

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Bunching and anti-bunching are considered as fundamentally quantum phenomena which could not be described in the classical field framework. In this paper we show that, opposite to this very common opinion, bosonic and fermionic (as well as anyonic) correlations can be described with the aid of classical random fields. We present a model of bunching and anti-bunching of classical random (Gaussian) bi-signals. Thus quantum and classical signal theories (and, in particular, classical and quantum optics) are much closer than it is typically assumed. By our model [1], prequantum classical statistical field theory (PCSFT), quantum mechanics can be considered as a formalism for calculation of averages with respect to classical signals combined with a rather strong random background field, so to say vacuum fluctuations. The presence of such a background random field is the cornerstone of PCSFT; quantum correlations can be represented as classical field correlations only by taking into account the background field, cf. SED. In PCSFT quantum entanglement is reduced to classical correlations ("renormalized" by subtraction of the contribution of the correlations with respect to the background field). Thus quantum randomness was finally reduced to classical randomness, but in a tricky way. Quantum correlations can be so strong (that they violate Bell's inequality) only due to the presence of the additional correlations inside the common background field. By PCSFT composite systems are not independent even for factorizable quantum states. Thus "nonlocality" induced by the background field is even stronger than "quantum nonlocality". However, there is nothing mystical in such "nonlocality" of classical signals coupled through the common random background.

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Generic non-Fermi-liquid behavior in metallic helimagnets

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Itinerant helimagnets have a very rich phase diagram as a function of temperature, magnetic field, and pressure. The broken continuous symmetries in the various phases lead to distinct Goldstone modes. In a specific temperature regime, these soft modes in turn determine the dominant temperature dependence of the single-particle relaxation rate, the electrical resistivity, and the heat conductivity. Non-Fermi-liquid behavior of some observables is predicted to occur in all of the various phases.

T56

Mechanisms and economy of molecular machines

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RNA polymerases (RNAPs) and ribosomes are the molecular machines that read out the genetic information. Their function is central for rapid cell growth and fast growing cells from bacteria to cancer cells devote a substantial fraction of synthetic activity to making ribosomes. In my talk, I will discuss quantitative aspects of the synthesis and use of these machines that are related to physiological constraints due to fast cell growth, focussing on the bacterial case.

In the first part of the talk, I will discuss how the transcription of ribosomal RNA (rRNA) can be understand as the solution to a traffic problem: rRNA transcription is typically characterized by dense traffic of RNA polymerases along the rRNA genes, very different from the typical situation for mRNA-encoding genes [1,2]. We therefore asked whether there are specific constraints that govern transcription in a dense traffic situation. This perspective allowed us to propose novel functions for termination/antitermination systems in bacterial rRNA transcription.

In the second part of the talk I will discuss 'economic' questions concerning the allocation of RNAPs to rRNA and mRNA transcription: Even though the dense traffic transcription on rRNA genes applies only to a small number of genes, these genes dominate the total cellular transcription. A longstanding question in bacterial physiology is whether a stop of rRNA transcription (which occurs in some stress responses) indirectly affects all other genes as more RNAPs becomes available for transcribing them. We address this question quantitiatively with an RNAP partitioning model [3] and test several proposals that have been made to answer this question. Our model suggests that such effects should be relatively small. The model is also used to determine the growth-rate dependence of transcription rates [3], an important ingredient to understand the performance of genetic circuits under different physiological conditions [4].

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Superconducting qubits grow up: Quantum coherence in circuits with many degrees of freedom

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Quantum coherence in superconducting circuits has been a fruitful playground for theorists and experimentalists seeking possible routes towards quantum computation, or teaching microwave photons new quantum optics tricks. While coherence times in such circuits have seen a remarkable increase of 5 orders of magnitude over the last decade, a different property has remained largely stagnant: following the "simpler is better" mantra of quantum coherence, circuits across all borders between phase, flux, and charge qubits, consistently employ less than a handful of circuit elements. A recent experiment with a new circuit composed of over 40 elements, dubbed "fluxonium", could be the kick-off for a paradigm change and make the world of superconducting circuits a lot bigger.

In this talk, I will discuss the obstacles and successes in achieving quantum coherence in superconducting circuits. I will showcase their applications in circuit QED, and present our work on developing theory for circuits with many degrees of freedom.

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T58

Graphene ratchets

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The ratchet effect, which is the induction of a dc current by an ac force in the absence of any net bias, represents one of the most intriguing phenomena in non-equilibrium transport. For graphene, one expects that its gapless and chiral nature negatively affects ratchet effects, because it hinders the confinement of electrons. Despite this expectation, a ratchet mechanism that is particularly efficient in graphene exists [1]: It is based on barriers in which the, say, left half is modulated by an ac gate voltage. Then electrons entering the barrier in evanescent modes from that side may be excited to propagating modes. Evanescent mode entering from the right, by contrast, decay before reaching the driving region. This mechanism is rather efficient in graphene, because all evanescent modes within a certain energy range contribute. The corresponding mechanism in a two-dimensional electron gas works only with modes that fulfill certain resonance conditions, which leads to a much smaller current.

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Bound states in non-equilibrium statistical physics

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In this talk we consider the problem of bound states in non-equilibrium statistical physics. For the consideration of bound states in non-equilibrium systems we need a kinetic equation. In the conventional kinetic theory, kinetic equations are derived under the assumption of "weakening of initial correlations" Under this condition, the build up of correlations (especially bound states) cannot be described. That finds its expression in the on-shell T-matrix in the Boltzmann equation. In order to take into account bound states we must

– modify the condition of weakening of initial correlations (partial weakening of initial correlations)

or

– use the Kadanoff-Baym equations to describe the influence of the initial state.

In this talk we focus on the second possibility and discuss kinetic equations with reactions.

T60

Some novelties in nonlinear plasmonics

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Nonlinear surface Plasmon oscillation (SPO) experiments were carried out, using an SPO Near Field Scanning Tunneling Microscope (STM), where the SPO-s were excited by a quasi-continuous semiconductor laser (670nm), furthermore using a femtosecond high intensity Ti:Sa laser to excite SPO-s in the Kretschmann geometry. In this latter case the SPO emitted light or electrons were detected.

In the first case enormous amplification of the electromagnetic field was found at special spots of the surface of a thin gold film, where STM signals were observed even at zero STM bias, which remained different from zero (extrapolation from the laser intensity function measurements) even at zero laser intensity.

In the second case spaser-like behaviour was found at very high laser intensities and high energy electrons were observed.

SPO emitted photon-photon intensity correlation measurements were also carried out with a CV He-Ne laser, where antibunching properties of the photons were found. The theoretical interpretation of our experimental findings is also given.

Quantum engines via measurements on non-Markovian time scales

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The anomalies of work, heating or cooling induced by frequent perturbations of open quantum systems are intimately related to the little-explored quantum correlations (entanglement or discord) that arise between the system (e.g., a qubit) and a thermal bath because of their coupling. Such correlations, which have previously eluded attention, have been shown by us both theoretically [1-4] and experimentally [5] to profoundly change the dynamics of the bath and the system once we perturb the system within the bath-memory (non-Markovian) time scales. The required perturbations can either be effected by frequent projective measurements of the qubit energy, or by its frequent modulation (ultrafast driving), giving rise to novel, anomalous regimes: a) Quantum heat engines (QHE): We present a hitherto unexplored QHE design, based on anomalies that arise from frequent quantum nondemolition (QND) measurements or phase flips of a qubit in contact with a non-Markovian bath [1,4]. Either operation results in a non-equilibrium state that starts evolving and can close a cycle via qubit-modulation by a piston, e.g., a coherently-driven oscillator mode. An intriguing anticipated consequence of such QND operations is the ability to extract net work (from the qubit to the piston) using a single bath, although such operations do not acquire information that can be converted into work, as opposed to Maxwell's demon. This anomaly may appear to contradict the second law, but in fact it does not, once the measurement or phase-flip cost in energy and entropy is accounted for. b) Entanglement-based QHE: Two or more qubits coupled to the same bath mode have recently been predicted by us to be inevitably entangled via the bath [6]. This entanglement is expected to principally affect the QHE performance. c) Non-Markovian quantum refrigerator (QR): Ultrafast cooling (purification) of qubits, may be attained at non-Markovian time-scales by frequent quantum measurements or phase shifts [3,5]. It allows us to put forward a novel, highly-compact, QR design which consists of a single qubit simultaneously coupled to hot and cold non-Markovian baths. Phase flips of the qubit at high rates are shown to cause refrigeration: Heat may then flow from the cold to the hot bath via the qubit. The third law is upheld: under no circumstances can the bath refrigeration attain absolute zero.

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T62

Finding hidden entanglement

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Quantum information applications usually require entanglement in the form of pure maximally entangled pairs. In general, however, states can be in incoherent mixtures of pure states. A state is said to be distillable if any maximally entangled singlets can be extracted from it, using only local operations and classical communication. In Hilbert spaces larger than 2x3, there are now known to exist entangled states from which no maximally entangled pairs can be distilled – such states are called bound entangled [1] and have recently been observed in the laboratory using trapped ions [2] and linear optics [3]. The "Smolin state" [4] is a particularly curious example; for example, it maximally violates a certain class of Bell inequalities [5], which is surprising, since one might naively expect that maximal demonstrations of quantum nonlocality would occur for pure quantum states, i.e., states with zero entropy. Also, the Smolin state has the interesting property that it can be distilled when a single party has possession of more than one of the four qubits.

The Smolin state is the incoherent sum of four 4-qubit states, each of which is the tensor product of two maximally entangled Bell states. To create it, we use spontaneous parametric down-conversion to produce photons pairs that are simultaneously entangled ("hyperentangled" [6]) in polarization and spatial mode. By combining the results of four simultaneous but incoherent processes, we are able to realize the desired state, which we can then characterize by quantum state tomography. An important feature of our bound entanglement source is that it is tunable: we can easily vary the coherence between the different creation processes, or add noise to the state, and thus observe transitions between regions of bipartite entanglement, multipartite entanglement, bound entanglement, and full separability.

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Quantum-to-classical transition of single-photon counters

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Optical detectors play a central role in the development of future quantum technologies [1]. For example, measurement-driven information processing, quantum key distribution, and state engineering rely more and more on precisely mastering single-photon counting. Here, using quantum detector tomography, a method that provides a complete description of the measurement device, we experimentally demonstrate how the specific quantum features of two different counters are degraded under external parameters [2]. We thereby show in a quantitative way how the decoherence processes, well-known in the case of quantum states, act at the level of quantum detectors. Our work witnesses the transition between the full-quantum operation of the measurement device, where the quantum probabilities have no classical equivalent, to the "semi-classical regime", described by a positive Wigner function, where the quantum fluctuations can be in principle classically described. The exact border between these two regimes is determined and experimentally measured. Moreover, we illustrate how such a transition manifests itself when the detector is used to herald the preparation of a target state, a paradigm for photonic quantum technologies.

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T64

Systematical effects in WMAP data and looking forward to the Planck data release

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Previously, by re-analyzing the Wilkinson Microwave Anisotropy Probe (WMAP) raw data, we have seen significantly different cosmic microwave background (CMB) results to the WMAP official release, especially at the largest-scale structure detectable for the CMB anisotropy – the $l = 2$ component, which is also called the CMB quadrupole. In this report, I will introduce the discovered differences, and then explain the possible reasons of the differences, especially why the WMAP official release should be questioned. Many people believe that the Planck mission will not have the same problem like WMAP; however, we have found out that this is wrong, and it's probably more difficult than we thought to reliably detect the CMB large scale anisotropy structure. We have also provided a way to obtain a relatively better CMB quadrupole estimation, and studied the probability of obtaining a quadrupole power estimation that is accurate to a certain level.

Controversy between Einstein and Bohr after 75 years, its actual solution and the consequences for the present

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The scientific community is still convinced that the controversy (in 1935) between Einstein and Bohr was decided definitely in 1982 when it was shown experimentally that Bell's inequalities (derived in 1964) were violated. The Copenhagen quantum mechanics has been accepted as the only theory of microworld as it has been commonly believed that the given inequalities have been valid in the framework of hidden-variable theory (corresponding to Einstein's ontological requirements). However, they were derived on the basis of the assumption valid only in classical physics (not in any quantum alternative). It means that the hidden-variable theory must be taken as fully acceptable. On the other side serious arguments may be brought against the Copenhagen quantum mechanics (internal contradictions in mathematical model as well as experimental data contradicting predictions in decisive way). All these arguments have been summarized in [1]; corresponding details being found in papers quoted there.

However, some important consequences have followed from the given results, which will be shown in the poster (together with main arguments):

1. Even if both the quantum alternatives have started from Schrödinger equation their physical contents have been fundamentally different; the original physical interpretation of Schrödinger solutions having been strongly deformed by the requirement put by Bohr on the corresponding Hilbert space formed from the given solutions.

2. The hidden-variable theory has been represented practically by the solutions of Schrödinger equation when any additional conditions have not been put on the corresponding Hilbert space.

3. There is only a smaller difference between the Schrödinger equation and classical physics as all basic solutions (characterized always by one Hamiltonian eigenfunction only) correspond to those of Hamiltonian equations and all superpositions correspond to the statistical combinations of classical states. It does not hold fully in opposite way in the case of discrete Hamiltonian spectrum as the Hamilton equations admit always all possible energy values.

4. The Schrödinger equation (or the hidden-variable theory) may represent the common theory of macroscopic and microscopic worlds if one admits that the corresponding quantization exists in the macroscopic world, too, when fully negligible (immeasurable) differences exist between corresponding discrete energy values.

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T66

Indirect control of anomalous transport in a system of two coupled Brownian particles

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Systems under non-equilibrium conditions can display new features as well as unexpected phenomena and processes which in equilibrium systems are forbidden by fundamental laws. One of the most prominent examples include the phenomenon of negative mobility (conductance, resistance): when a constant force is applied to a mobile particle, it moves in the direction opposite to that of the force. It is impossible in equilibrium states because it would violate the second law of thermodynamics.

For a one-particle system, the simplest, one dimensional model is formulated in terms of the Langevin equation for a particle moving in a symmetric spatially periodic potential, biased by a static force and driven by an unbiased harmonic force. This system is out of equilibrium and displays both absolute negative mobility around zero static applied force (the linear response regime) and negative mobility in the non-linear response regime. In the linear response regime, the long-time averaged particle velocity tends to zero when the static force tends to zero. In the nonlinear response regime, the particle velocity can tend to zero even if the static force is far from zero. It is known that the corresponding overdamped system does not exhibit negative mobility and the inertial term in the Newton equation is absolutely necessary for the negative mobility to occur. However, when the particle is coupled to another particle, negative mobility can arise. We present a minimal model and propose a scenario in which only one (say the first) particle is dc-biased by a constant force and ac-driven by an unbiased harmonic signal. In this way we intend to achieve two aims at once: (i) negative mobility of the first particle, which is exclusively induced by coupling to the second particle and (ii) indirect control of the transport properties of the second particle by manipulating the first particle only. For instance, the sign and amplitude of the averaged stationary velocity of the second particle can be steered by the driving applied to the first particle. As an experimentally realizable system, we propose two coupled resistively shunted Josephson junctions. We demonstrate that the second junction can exhibit both absolute negative resistance near zero bias and negative resistance in the non-linear regimes. These anomalous transport features occur for restricted windows of the coupling constant.

Nonequilibrium entropy production for open quantum systems

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We consider quantum systems driven by arbitrary time-dependent parameters. We derive exact microscopic expressions for the nonequilibrium entropy production and entropy production rate, for closed as well as for open systems weakly coupled to a heat reservoir. Our results are valid arbitrarily far from equilibrium, beyond linear response. By using the two-point energy measurement statistics for system and reservoir, we further obtain a quantum generalization of Seifert's integrated fluctuation theorem.

T68

Quantum thermostatics and generalization of Wien's law

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The contribution concerns an important branch of the thermal physics, quantum thermostatics, which deals with the properties of quantum systems near the thermal equilibrium. Despite the fact that such systems, strictly speaking, do not exist in the nature, they satisfactorily approximate many real systems and provide a firm basis for their microscopic description. Assuming that any adiabatically insulated quantum systems at thermal equilibrium can be identified with a set of stationary oscillators of constant eigen-frequencies ω and that the temperature T is Lorentz invariant, it is shown that there exists an adiabatic invariant (kT/$\hbar\omega$) = const., which has to be, in contrast to the prevailing opinion, also Lorentz invariant. This relation, which we tentatively call generalized Wien's law, enables one to measure the temperature of any quantum system by analyzing the spectral distribution of its eigen-frequencies. Two examples of such systems, de Broglie ideal gas and Stewart-Kirchhoff's cavity are discussed in detail.

Testing the applicability of quantum theory to event-based processes

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We analyze a single-particle Mach-Zehnder interferometer experiment in which the path length of one arm may change (randomly or systematically) according to the value of an external two-valued variable x, for each passage of a particle through the interferometer. Quantum theory predicts an interference pattern that is independent of the sequence of the values of x. On the other hand, corpuscular models that reproduce the results of quantum optics experiments carried out up to this date show a reduced visibility and a shift of the interference pattern depending on the details of the sequence of the values of x. The proposed experiment will show that:(1) it can be described by quantum theory, and thus not by the current corpuscular models, or (2) it cannot be described by quantum theory but can be described by the corpuscular models or variations thereof, or (3) it can neither be described by quantum theory nor by corpuscular models. Therefore, the proposed experiment can be used to determine to what extent quantum theory provides a description of observed events beyond the usual statistical level.

T70

Thermal issues in Casimir forces between conductors and semiconductors

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For the past decade, there has been a heated controversy concerning the temperature dependence of the Casimir force between real conductors. It was proposed by several authors that the traditional approach based on an ideal metal is inconsistent with fundamental principles of electrodynamics, thermodynamics, and statistical mechanics, and rather that the zero-frequency mode corresponding to the TE polarization has to be excluded, consistent with the Drude model for the permittivity of a metal. Other authors criticized this view, saying that it violated quantum thermodynamics for a perfect lattice, and was inconsistent with precision measurements of the Casimir force. Theoretically, the consensus seems to favor the exclusion of the TE zero-mode, and now new experiments at micron separations, where the modification of the thermal prediction should be by a factor of 2, apparently strongly favor this view as well. This talk will review the controversy, present both points of view, and indicate likely resolutions. A similar controversy, involving the TM modes for semiconductors, will also be discussed.

Using macroscopic discontinuities in magnetic susceptibility within a loop of type-II superconducting wire to measure global decoherence rate

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We have observed a phenomenon of a periodic "staircase" of macroscopic jumps in the admitted field, as the magnitude of an externally applied magnetic field is smoothly increased or decreased upon a superconducting loop of type II niobium-titanium wire which is coated with a non-superconducting layer of copper. Large temperature spikes were observed to occur simultaneously with the jumps, suggesting brief transitions to the normal state, assumed to be caused by en masse motions of Abrikosov vortices. An experiment that exploits this phenomenon to measure the speed of the global decoherence of a large superconducting system will be discussed, and preliminary data will be presented.

T72

Engineering of Dirac cones in two-dimensional crystals

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We consider several examples of 2D crystals where the low energy properties can be described with a 2 x 2 Hamiltonian with a spectrum exhibiting several Dirac cones. These cones are characterized by a linear dispersion relation, and by a topological number, or "charge", related to a Berry phase associated to the spinorial structure of the wave function. For example, the graphene spectrum has a pair of Dirac cones with opposite Berry phases ($\pm\pi$). We study under which conditions these Dirac cones can be manipulated, created or suppressed, through a modification of band parameters, under the condition of conservation of the total "charge". We have considered several different cases:

We have shown that a single pair of Dirac points with *opposite* "charges" merge always at a symmetric point G/2 of the reciprocal space, where G is a reciprocal lattice vector. In the specific case of graphene, this situation is reached by a modification of one among the three hopping parameters between nearest neighbors. At the topological transition, the spectrum has the remarkable property to be linear in one direction and quadratic in the other direction (*semi-Dirac point*). We derive a universal Hamiltonian that describes the vicinity of the transition, characterized by three parameters, a mass, a velocity and a driving parameter Δ whose values are related to the band parameters of any 2D crystal with time-reversal and inversion symmetries. This model describes continuously the coupling between valleys associated with the two Dirac points, when approaching the transition $\Delta = 0$. We find a general scaling law for the energy levels which evolve continuously from a square-root to a linear dependence, with a new dependence at the transition (the *semi-Dirac* point).

A pair of Dirac points with *same* charge can also merge into a single point with double charge 2π, characterized by a gapless quadratic spectrum. This transition occurs in twisted graphene bilayers. This merging belongs to a different universality class, and the scaling behavior of the Landau levels is different from the previous case.

The case of strained bilayer is particularly interesting since the spectrum exhibits a pair of four Dirac points. Under strain, these four Dirac points can be manipulated and may disappear. Different types of merging can occur, either the merging of two Dirac points with opposite charges, or the merging of three Dirac points ($\pi, \pi, -\pi$) into a single one (π) (fig. c).

In each case, we obtain the Landau levels spectrum and we calculate the number of zero energy modes, and compare the exact spectrum with its semiclassical approximation. Finally, we discuss several other physical systems where such motion and merging of Dirac points can occur like the organic salt (BEDT-TTF)2 I3 and optical lattices of cold atoms. More exotic examples can be found in the Hofstadter spectra for various lattices in a strong magnetic field.

Collaborators: F. Piéchon, J.-N. Fuchs, M.-O. Goerbig, R. de Gail, P. Delplace, P. Dietl

Flows of quantum information quantities

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We demonstrate that quantum transport setups permit a natural and constructive definition of flows of Renyi entropies. We discuss the many-contour generalization of Keldysh technique that makes possible the pertubative computation of these flows and review some results, mostly concentrating on quantum point contacts.

T74

Dynamics in a model for quantum measurements and insight in the quantum measurement problem

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The talk will advocate our Dreimännerarbeit or Opus Magnum on the quantum measurement problem [2]. This work presents an extensive overview of the literature in the field and then elaborates on the dynamical solution of the Hamiltonian model for a quantum measurement presented in Ref. [1].

Quantum measurements have confronted theorists with many fundamental questions, such as: What determines the basis in which the collapse takes place? Why do Schrödinger cats disappear? What is the minimal interpretation of quantum mechanics? The deepest question is the so-called quantum measurement problem: Can quantum mechanics, despite its probabilistic nature and wave aspects, explain the fact that individual measurements produce individual outcomes?

We shall answer these questions by solving the dynamics of a fairly realistic Hamiltonian model for a quantum measurement: a spin 1/2 is measured by an Ising magnet coupled to a bath. In this process Schrödinger cat terms disappear quickly while producing small multi-particle correlations, which themselves disappear. The magnetization will go from zero in the initial metastable paramagnet to +/- m_F in the final up- or down ferromagnetic state. This transition is triggered by the measurement. The solution to the quantum measurement problem will be related to the irreversible dynamics, which brings the magnet to one of its stable states. The tested spin is coupled to it and will thus also go to a unique state, correlated with the state of the magnet.

A specified version of the statistical interpretation arises as the minimal one. Since it is easy to grasp for students, it will be advocated as the primary one for teaching.

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Spin pumping in magnetic tunnel junctions and topological insulators: Theory and experiment

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The pursuit of the "second-generation" spintronics has been focused on harnessing coherent spin states. The salient examples of phenomena involving both coherent spins and their time evolution is the spin-transfer torque (STT) and its Onsager reciprocal effect, termed spin pumping because it occurs in setups without applied bias voltage, where microwave driven precessing magnetization of a single ferromagnetic (F) layer emits pure spin current into adjacent normal metal (N) layers. While pumped spin current has been detected by converting it into ~ 10 nV voltage signal in N1|F|N2 junctions, a puzzling and much larger signal ~ 1 μV was measured in our recent experiments [1] on F|I|N tunnel junctions with AlO_x insulating barrier I. This observation is unexpected in both standard scattering theory and nonequilibrium Green function (NEGF) in the rotating frame [2] approaches to pumping which predict no signal at adiabatic level $\sim \omega$. However, neither of these two approaches is capable of taking into account strong spin-orbit coupling (SOC) directly at the F|N pumping interface, such as the Rashba one demonstrated to exist in recent experiments on STT in F|I|N junctions. Unlike the recent theoretical efforts on STT in the presence of SOCs, very little is known about such effects on spin pumping. Here we discuss a novel solution [3] to time-dependent NEGFs, which describes pumping in the presence of SOC exactly at the level of one microwave photon absorption or emission processes, to explain $\sim \omega$ voltage signal observed experimentally [1]. We also discuss pumping into 2D topological insulators (TI) whose helical edge states lead to quantized pumped spin current even at very small input microwave power thereby generating giant spin battery effect [4]. Finally, the unique voltage signal of spin pumping in vertical F|TI junctions can be employed to detect quantum Hall liquid on the surface of three-dimensional TIs in proximity to F.

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T76

Transient-regime transport in nanostructures

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In structures consisting of a quasiballistic, nanometer-size active region attached to much larger reservoirs, electronic transport cannot be described by using the semiclassical Boltzmann transport formalism. Rather, the active region is an open quantum-mechanical system whose dynamics is governed by coupling to the contacts and by the rapid dephasing inside the contacts. To correctly describe transport in this regime, one must resort to a quantum-mechanical scattering formalism that properly accounts for the open system nature of the current-limiting active region and adequately eliminates the large number of degrees of freedom that exist in the leads [1].

Here, we present a computational method for calculating the transient dynamics of 2-terminal nanostructures by using several convenient approximations to reduce the complexity of the described problem [2]. We work within the open systems formalism [3], where the active region/environment system is represented as a composite system Hamiltonian with an environment, active region, and interaction terms and the initial statistical operator is assumed to be of a tensor-product form that guarantees the existence of a non-Markovian subdynamics.

In particular, we calculate the transient response of a quantum point contact (QPC) formed by the split-gate technique on a two-dimensional electron gas. The QPC, an open system coupled to reservoirs, is modeled by a solution to the coupled, two-dimensional Schrödinger and Poisson equations using a discrete subset of the normal-mode basis. The normal modes are projected onto the traveling-wave solutions that match the incoming reservoir plane waves. The occupation of the open system states carries the information about the time evolution and is calculated by solving a coarse-grained quantum master equation with suitably defined open system/contact interaction Hamiltonians. The final electronic transient response is obtained by enforcing the current continuity across the open system/contacts boundaries through a time-dependent reservoir drift wavevector. We investigate the transient current response to a voltage step and its dependence on the split-gate bias and relaxation time in the contacts [4].

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Inelastic effects on the electronic current noise through nanojunctions

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We study [1] the effects of vibrational degrees of freedom in nanojunctions on the electronic current (shot) noise presently being addressed in ongoing experiments on atomic wires and molecules [2]. Working in the experimentally relevant limit of weak electron-vibronic coupling and using the extended non-equilibrium Green's function formalism with counting field [3, 4] we evaluate the inelastic contribution to the current noise for generic junctions [1], thus extending previous studies addressing only the mean current [5, 6, 7]. The result consists of combinations of terms specific for a given junction and expressed via its structural properties, which can be calculated with, e.g., state-of-the-art ab-initio techniques, and universal, i.e., junction-independent, analytical functions of vibration frequency, voltage, and temperature. We also discuss effects of non-equilibrium phonon occupation (heating), their proper theoretical description within the presented formalism, and their physical relevance and interpretation [8]. Finally, we briefly comment on the connection of our theoretical predictions with the preliminary (unpublished) experimental findings.

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T78

Entanglement and coherence: Differences and similarities

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Entanglement and coherence both decay due to environmental (heat bath) effects. Apart from the well-known fact that decoherence occurs exponentially and disentanglement occurs with a sudden death, there are many other differences. Here, we concentrate on the effects of temperature T along in the absence of dissipation. Thus, whereas the effect of T on decoherence increases exponentially with time [1], the effect of T on disentanglement is constant for all times [2], reflecting a fundamental difference between the two phenomena. Also, the possibility of disentanglement at a particular T increases with decreasing initial entanglement.

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Degradation and protection of entanglement between solid state qubits

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A crucial challenge for future quantum technologies is to protect fragile entanglement against environment-induced decoherence. Various Dynamical Decoupling (DD) sequences emerged recently as high-order decoherence suppression schemes for single qubit systems. How quantum correlations in multi qubit systems can be effectively preserved via DD is still a open issue. The problem is particularly severe in solid state implementations of quantum bits, which are typically affected by broadband noise [1].

We study entanglement degradation of two non-interacting qubits subject to independent baths with broadband spectra typical of solid state nano-devices [2]. We obtain the analytic form of the concurrence in the presence of adiabatic noise for classes of entangled initial states presently achievable in experiments. We find that adiabatic (low frequency) noise affects entanglement reduction analogously to pure dephasing noise. Due to quantum (high frequency) noise, entanglement is totally lost in a state-dependent finite time.

As a first step towards the long-term goal of preservation of quantum correlations between solid state qubits, we investigate the possibility to preserve bipartite entanglement between two superconducting qubits subject to quantum bistable fluctuators, extending control tools developed for solid state single qubit gates in Ref. [3]. In the absence of interaction between the qubits, we investigate how the phenomena of entanglement revival for non-Markovian noise and the entanglement sudden death for Markovian noise are influenced by the DD. Protection of entanglement via the quantum Zeno effect is found under special conditions.

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T80

Ultrafast thermometry using quantum coherence

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The macroscopic parameters of the physical environment surrounding a target system affect the microscopic quantum states of the constituent molecules within the system. For example, the quantum statistics of atomic or molecular states in thermal equilibrium are dictated by a Boltzmann distribution function that is characterized by the temperature of the environment. Usually, an electromagnetic field can strongly interact with those microscopic states locally without affecting the macroscopic property of the system. Thus, laser probes for measuring the population distribution have been very widely used to achieve accurate nonintrusive thermometry. With the advent of new laser sources with shorter pulse durations [up to a few femtoseconds (fs)], along with the availability of high-power lasers and the ability to control accurately the phase properties required for obtaining pulses of arbitrary shape, ultrafast techniques have become indispensable diagnostic tools [1].

The ultra-short pulses have an extremely wide bandwidth for simultaneous coupling of a number of internal states of a target system for a very short time duration (a few to 100 fs), causing multiple coherent excitations that are all in the same phase [2]; e.g., a 532-nm laser with a 100-fs pulse duration has a bandwidth of $350\ cm^{-1}$ that typically couples many molecular states in the target system. Those coherence excitations function in much the same way as a group of classical coupled harmonic oscillators with slightly different characteristic frequencies. The higher the temperature, the greater is the number of oscillators. Once the pulse ceases, the initial coherence begins to randomize. This decoherence process contains the thermometric information that is extracted by coupling a suitable combination of lasers to generate and measure the coherent anti-Stokes Raman scattering signal [3]. However, thermometric measurements become complicated by multiple interfering molecular coherences that are generated by different pairs of photons from the wide bandwidth of the pump beam.

We will focus on revisiting the effect of quantum coherence on thermometry in the ultrafast regime using the ultra-short laser beams. We will discuss the advantages and challenges involved in ultrafast thermometry and present some recent exciting diagnostic results obtained by our group using phase-manipulated shaped pulses [4].

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Open quantum random walks

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Open quantum random walks (OQRW) are introduced as a tool for the formulation of dissipative quantum computing algorithms and formulated as quantum Markov chains on graphs. Examples of OQRWs show a rich dynamical behavior. It is shown that on finite graphs OQRWs converge towards a unique stationary state, as is needed in dissipative quantum computing and dissipative state engineering. Furthermore, promising dissipative mechanisms of transport of excitations can be implemented in the formalism, which makes them interesting candidates for the investigation of quantum efficiency.

T82

Probing the canonical commutator of massive mechanical oscillators

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While the canonical commutation relation is one of the main cornerstones of quantum mechanics, in many theories of quantum gravity the commutator acquires a small modification. However, such modifications remain outside the reach of experiments as of yet.

Here we show how the commutation relation of a massive mechanical oscillator can be probed using pulsed opto-mechanical systems. With the mass of the oscillator being close to the Planck mass, we show that certain theories of quantum gravity that predict a deformation of the commutation relation can be tested. The proposed setup thus allows to distinguish between the classical, quantum and even quantum gravitational regimes.

What is quantum field theory, technologically, mathematically, and philosophically?

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In the wake of the introduction of quantum mechanics in 1925, Niels Bohr spoke of the "mathematical instruments" of higher algebra as playing an essential part in the new theory. The expression "mathematical instruments" was not merely a convenient metaphor. Bohr saw quantum mechanics as a mathematical technique or technology for predicting, in probabilistic terms, the outcomes of quantum experiments, rather than for describing quantum objects and processes, in the way classical mechanics would. Accordingly, Bohr also spoke of a new type of relationships between mathematics and mechanics, and mathematics and nature, established by Heisenberg's theory. By the same token, a new philosophy of physics was also at stake.

Taking Bohr's argument as point of departure, this paper argues that the situation takes an even more radical form in quantum field theory and the experimental physics in the corresponding energy regimes. Just as in the case of low-energy regimes, treated by quantum mechanics, the practice of experimental physics in (high-energy) regimes treated by quantum field theory, no longer consists in tracking what already happened in nature, but in creating new configurations of experimental technology in which new phenomena are observed. The practice of theoretical physics no longer consists of offering a mathematical description of the ultimate constitution and workings of nature. It consists of establishing the relationships, necessarily probabilistic in character, between two "technologies:" the "mathematical instruments," comprising the formalism, and measuring instruments involved. Quantum field theory, however, is characterized by a much greater complexity than quantum mechanics. This complexity arises in view of the following three, correlative, circumstances: (1) a more complex nature and handing of the mathematical formalism of the theory (reflected in part in the necessity of renormalization); (2) more complex configurations of phenomena observed and hence measuring apparatuses involved; and (3) a more complex character of the quantum-field-theoretical predictions and, hence, of the relationships between mathematical and measuring instruments involved in high-energy physics. The aim of present paper is to explore this greater complexity of quantum field theory, under the epistemological conditions that it shares with quantum mechanics. As all technologies, the technologies, mathematical and properly technological, of quantum field theory can, and even one day must, become obsolete. This, however, is a good thing, because, since nature is never obsolete, we will be compelled to invent new mathematical and experimental technologies, new configurations of measuring instruments. In quantum physics, from quantum mechanics to quantum field theory and beyond, we experiment both with nature and (by inventing new mathematics of quantum theory) with mind.

T84

Relativistic quantum information

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Relativistic quantum information science investigates new effects that emerge when information encoded on relativistic quantum systems is studied. I will discuss two new results: entanglement between the future and the past; and a consistent quantum field theory for closed timelike curves.

It is known that the quantum vacuum of flat space is entangled between spacelike separated regions. This is the basis of the Unruh effect [1] in which accelerated observers see thermalization of the vacuum due to this entanglement. We have recently shown that vacuum entanglement also exists between timelike regions of space time, i.e. between the past and the future [2]. We will describe how this entanglement can be efficiently extracted via stationary detectors with scaled energy levels [3] and discuss applications.

Closed timelike curves, i.e. time machine to the past, are allowed by exotic solutions of general relativity but are incompatible with quantum field theory. A consistent treatment of qubits interacting with CTC's exists [4], but it is not a field theory. We describe a non-standard quantum field theory [5] and prove that it reduces to ref. [4] in the limit of point like 2-level systems [6]. We investigate the behaviour of this theory for different field states and simple CTC interactions.

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Hadron interferometry with neutrons

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Matter wave interferometry provides new information about basic features of quantum physics. Neutrons experience nuclear-, electromagnetic- and gravitational interactions and they appear as particle or as waves depending on the experimental situation. Widely separated coherent neutron beams can be produced and manipulated within a perfect crystal interferometer. The verification of the 4π spinor symmetry, the spin-superposition law and various gravitational effects have been verified [1]. Weak and post-selection measurements provide new information about the physical situation in the far-field region of a wave packet and show how nonlocal interaction effects can be explained by far reaching parts of the partial waves constituting a wave packet. Coherence and decoherence are basic features of the wave picture of matter, which influence the dynamical and the topological quantum phases as well. Related experiments deal with the interaction of neutrons with noisy magnetic fields where phase fluctuations and photon exchange processes come into play. More recently quantum contextuality has been investigated, which indicate an intrinsic entanglement of different degrees of freedom [2]. This may have consequences on quantum communication and quantum information systems. In a further step Kochen-Specker phenomena have been investigated which shows strong correlations of basic features in quantum and particle physics.

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T86

Relaxation processes in a Bose-Einstein condensate

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We have obtained a kinetic equation for the relaxation of excitations (bogolons) in a Bose-Einstein condensate and have computed the eigenvalues (decay rates) and eigenmodes of the bogolon collision operator for the linearized kinetic equation as a function of the condensate order parameter. The eigenvalue spectrum and eigenmode expansion of the non-equilibrium bogolon distribution has many analogies to that of the Boltzmann equation [1] and the Uehling-Uhlenbeck equation [2] that we obtained earlier.

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Dipolar quantum gases from a few-body perspective

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Dipolar interactions between trapped atoms or molecules (see for example Lahaye et al. [1] for a review) provide an interesting new scenario where the two-body interaction becomes spatially anisotropic, being repulsive if the dipoles are aligned, but (partly) attractive when the dipoles can orientate head-to-tail. We discuss how in low-dimensional few-body systems with dipolar interactions, Wigner-localized states of different symmetry may emerge as a function of increasing coupling strength [2][3]. When set rotating, the vortex lattice in the bosonic case depends on the dipolar tilt angle. In much analogy to the vortices in quantum dots at strong magnetic fields, also in fermionic systems with dipolar interactions the vortices are revealed by the symmetry breaking through the anisotropic interaction. Progress with atom chips (see for example the review by Fortágh and Zimmermann [4]) opens exciting new perspectives for integrated systems [5]. In this context, we furthermore discuss a microscopic analogue of source-drain transport with ultracold bosonic atoms in a triple-well potential [6] and address how effects similar to Coulomb blockade in quantum dots and wires may occur with cold atoms.

The talk reviews recent work done in collaboration with with G. Bruun, J. Cremon, G. Eriksson, L.H. Kristinsdóttir, G. Kavoulakis, F. Malet and A. Wacker.

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T88

Quantum computing with magnetic insensitive states

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Trapped ions employing laser light have provided successful demonstrations of the basic elements of a quantum information processor (QIP). Despite these successes, scaling these technologies to achieve large scale universal QIP or more specialized quantum simulations remains challenging. The use of easily controllable and stable microwave sources instead of complex laser systems on the other hand promises to remove fundamental obstacles for scalability. An important remaining drawback in this approach, also shared by laser-based QIS, is the necessary use of magnetic sensitive states which is shortening coherence times considerably and the need to create large stable magnetic gradients in microwave based schemes. In this talk I will present a novel theoretical approach based on dressing magnetic sensitive states with microwave driving that addresses both issues and I will explain the experimental realization of the basic building blocks of this scheme to show that these dressed states are long-lived and permit fast quantum logic. This changes decisively the prospect of microwave-driven ion trap QIP and offers a new route to extend coherence times for all systems that suffer from magnetic noise such as neutral atoms, NV-centres and quantum dots.

[1] arXiv:1105.1146

Weak values in solid state systems: Charge sensing amplification and decoherence effects

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In a classical measurement it is possible to acquire information about the state of the measured system without affecting it. In a quantum measurement, instead, the detector's back-action cannot be avoided, as described, in the simplest version, by the the wave-function collapse [1]. In a more refined description, a quantum measurement is a continuous process of data acquisition by a detector, alongside gradual modification of the system's state. In this framework, weak (non-invasive) measurements are possible, wehere the limited information acquired by the detector corresponds to a weak back-action. A remarkable consequence is the emergence of a new quantum mechanical average, termed weak value (WV) [2] as a result of a weak measurement followed by a second strong one. The outcome of the first is conditional on the result of the second (post-selection). Weak values are complex numbers and their real part may take peculiar values, out of the range of eigenvalues of the measured observable. They are insightful quantities to address fundamental aspects of quantum mechanics, including the simultaneous detection of different observables. Recently weak values protocols have been employed for ultra-sensitive detection of small quantities in quantum optics [3].

Here, after introducing the concept of weak values, we briefly discuss recently proposed protocols for the observation of weak values in solid state systems. We address the detrimental effects of decoherence due to fluctuations of the system's parameters, and identify in what conditions peculiar weak values are still observable. We then focus on a recently proposed protocol [4] employing weak values to obtain ultra sensitive amplification of weak signals in the context of a solid state setup. We consider an Aharonov-Bohm interferometer where both the orbital and the spin degrees of freedom are weakly affected by the presence of an external charge to be detected. The interplay between the spin and the orbital WVs leads to a significant amplification even in the presence of finite temperature and voltage.

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T90

Mechanism of anomalous heating of trapped ions

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In the talk, we review the existing experimental results on anomalous ion heating in ion traps. We discuss theoretical approaches to describe the rate of ion heating and dependence of the rate on frequency of the trap, the distance between electrodes and their temperature. We present preliminary results on several mechanisms that have not yet been considered, and discuss the status and development of the current theoretical approach.

Mesoscopic non-equilibrium thermodynamics

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Concepts of everyday use like energy, heat, and temperature have acquired a precise meaning after the development of thermodynamics. Thermodynamics provides the basis for understanding how heat and work are related and with the general rules that the macroscopic properties of systems at equilibrium follow. Outside equilibrium and away from macroscopic regimes most of those rules cannot be applied directly. We present recent developments that extend the applicability of thermodynamic concepts deep into small-scale and irreversible regimes. We show how the probabilistic interpretation of thermodynamics together with probability conservation laws can be used to obtain kinetic equations for the relevant degrees of freedom. This approach provides a systematic method to obtain the stochastic dynamics of a system directly from its equilibrium properties. A wide variety of situations can be studied in this way, including many that were thought to be out of reach of thermodynamic theories, such as non-linear transport in the presence of potential barriers, activated processes, slow relaxation phenomena, and basic processes in biomolecules, like translocation and stretching.

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Transport from hot spots

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To demonstrate that the relative stability of non-equilibrium states can not be found from local criteria, Landauer showed that hot spots in locations of phase space that might be only rarely visited can be decisive. Later, Büttiker [1] and van Kampen [2], investigated the noise induced transport generated by hot spots in systems with overdamped Brownian motion dynamics.

In electrical circuits hot spots occur naturally at places where energy is dissipated. Here we propose a controlled experiment which can demonstrate the appearance of directed current as a consequence of a hot spot. We investigate transport generated in Coulomb coupled electrical conductors [3,4]. Coulomb coupled conductors permit separate directions of the heat and current flux [4]. In our model, one of the conductors is connected via only one lead to a hot reservoir. The other conductor connects to two leads. We investigate the minimal conditions needed to generate directed current flow for a system of two quantum dot conductors in which both energy and charge states are quantized. In quantum dots energy to current conversion can be optimal with one electron transferred for every heat quantum given up by the hot reservoir. We show that at the point of maximum power extraction the efficiency approaches one half of the Carnot efficiency. For heat to charge current conversion the energy dependence of transmission probabilities is essential: in contrast, our model also predicts a heat diode behaviour [5] with energy independent transmission probabilities.

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Efficient algorithm for optimizing adaptive quantum metrology processes

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Quantum resources such as entanglement can enable measurements to exceed the standard quantum limit, which is essentially due to partition noise as the particles randomly choose paths in an interferometer. Quantum measurement schemes relying on adaptive feedback are promising because accumulated information from measurements is exploited to maximize the information gain in subsequent measurements. However, devising such feedback policies is complicated and often involves clever guesswork, even for ideal scenarios without loss or noise. Creating feedback policies that work in practical circumstances where noise and loss are non-negligible may turn out to be infeasible.

We have developed new methods for constructing robust quantum measurement strategies using feedback. Our approach is based on machine learning and exploits state-of-the-art collective-intelligence algorithms. Our algorithm autonomously learns to perform phase estimation based on experimental trial runs, which can be either simulated or performed using a real world experiment. Our algorithm has so far yielded the most efficient feedback-based quantum measurement scheme to date for estimating an interferometric phase by feeding in a string of photons [1,2], and we are developing noise-resistant algorithms for constructing policies in realistic cases.

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T94

Can one see entanglement?

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Entanglement is one of the most fascinating aspects of quantum mechanics as it is far removed from our everyday sensory experience. It is an interesting question to see whether this is a fundamental limitation of our senses, or whether experiments can be designed to bring us closer to the quantum world.

To answer this question we consider what is probably the most sensitive Human "measurement device": the eye, capable of seeing a number of photons as low as 100. It has been shown [1] that macroscopic superpositions of this size can be in principle achieved by strongly amplifying (cloning) a photon from an entangled pair.

In earlier work [2,3] we have shown theoretically that one can violate a Bell inequality using these states, i.e. the choice of measurement basis can be done after amplification. However particular care must be taken when interpreting results of such experiments. To illustrate and to better understand what can be inferred from these results we perform an experiment where the amplification is provided by a "Black Box". We show that it is indeed possible to experimentally violate the Bell inequality with human eyes (or by standard threshold detectors) by selecting the basis after the amplifying "Black Box".

Surprisingly this is the case even when the black box in question is entanglement-breaking (in our case a measure and prepare cloner). Indeed any detection method with finite efficiency, such as threshold detectors does open up the detection loophole, explaining these results.

In fact entanglement can only be inferred if one assumes that what is measured is a qubit, i.e. one can only demonstrate the entanglement between the two initial photons.

Finally we present our measurements of both the retinal and post-retinal contributions to the human threshold of vision, and conclude that with finite efficiency threshold detectors, such as linear photodiodes or human eyes, it is impossible to distinguish a macroscopically entangled state from a classical one.

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Quantum chaos and thermalization in isolated many-body systems

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By means of exact diagonalization, we study level statistics, the structure of the eigenvectors, and few-body observables of one-dimensional bosonic and fermionic systems across the transition from integrability to quantum chaos. These systems are integrable in the presence of only nearest-neighbor terms, whereas the addition of next-nearest couplings may lead to the onset of chaos. We show that the eigenstate thermalization hypothesis, which is accompanied by the thermalization of the system, is valid whenever quantum chaos develops and it holds even if the system is in the gapped phase or if symmetries are mixed. We discuss the dependence of signatures of chaos on system size and particle statistics, and the use of delocalization measures as main indicators for the crossover from integrability to nonintegrability [1,2,3].

We also present results for the so-called diagonal entropy. This recently introduced quantity corresponds to the Shannon (information) entropy written in the energy basis and has been argued to be the proper definition of thermodynamic entropy in out-of-equilibrium quantum systems [4]. We show that the diagonal-entropy becomes equivalent to the equilibrium microcanonical entropy only when the system is chaotic [5].

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T96

Electron transport in large systems including fluctuating environment and many body effects

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The non-equilibrium Green's function (NEGF) method combined with density functional theory (DFT) is at present the workhorse algorithm for investigating electron transport in complex systems. In general the realism of these calculations depend heavily on our ability to deal with three fundamental issues: 1) the systems to investigate are typically large (in excess of 10,000 atoms); 2) the electrostatic potential may be determined by a dynamical environment (for instance a solvent); 3) many body effects may dominate the electrical response.

In this contribution I will present the development of a large scale electronic transport code based on NEGF+DFT and its application to systems containing a large number of atoms and possibly including inelastic effects of various origin. The code builds on SMEAGOL [1] and consists of three main elements: i) a parallel and threaded library to calculate the Green's function of the system based on the recursive Green's function method combined with an efficient and accurate calculation of the electrodes' self-energies [2], ii) an adaptive mesh algorithm to integrate the non-equilibrium Green's function to give the charge density, and iii) a many body expansion for incorporating non-elastic effects.

Then I will present three rather different examples of how the method works. First I will consider electron transport in nanostructures constructed on the Si (100) surface and show that our scheme is ideal to explain non-local STM experiments. Then I will briefly discuss how electron transport in large bio-molecules such as DNA [3] can be tackled and finally I will consider the competition between spin-flip inelastic electron tunneling spectroscopy and the Kondo effect in single magnetic atoms on insulating surfaces [4].

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Observations of Black Holes show the possibility of a widely separated accretion disk

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Observations of the UV-Optical continuum radiation from quasars using techniques of microlensing and reverberation have produced a picture that differs from standard black hole theory [1]. For the first discovered Q0957 lens, emission does not originate from the inner edge of an accretion disc at 6 R_g, but rather from an edge at 70 R_g, indicating action of a magnetic propeller. More than half the emission originates from a luminous ring at the light cylinder. On the other hand, in radio quiet lensed quasar Q2237 (Einstein Cross) the 6 R_g inner ring and also outer ring are seen [2]. Thus the radio loud and radio quiet quasars are in different spectral states, as would be expected for a source dominated by a rotating centrally anchored dipole magnetic field, as also modeled for Magnetars.

Of course black holes have no hair, but other solutions of the Einstein-Maxwell field equations pioneered by Abhas Mitra (ECO) and the magnetic variant by D.Leiter and S.Robertson (MECO) [3] allow extremely strong magnetic fields, whose co-rotation on the accretion disc creates the different quasar spectral states (radio loud/quiet) observed. Instead of an event horizon, these solutions have a physical surface whose redshift is so high that time dilation prohibits crossing the surface in a time exceeding the life of the universe. The ECO/MECO solutions have been found in analytical form, but not yet simulated.

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T98

From the adiabatic to the anti-adiabtic regime of phonon-assisted tunneling

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The promise of molecular electronics has generated intense interest in the interplay of molecular vibrations and resonant electronic transport. Two customary limits of phonon-assisted tunneling are the anti-adiabatic and adiabatic regimes, where the phonon frequency is either sufficiently large or sufficiently small as compared to the bare electronic hopping rate. In the former case the phonon can efficiently respond to hopping events by forming a polaron, thus suppressing the bare tunneling rate. In the latter case the phonon is too slow to track the electronic motion, having little effect on its rate. While each of these extreme limits is rather well controlled theoretically, the crossover between them is far less understood as it lacks a small parameter.

We conducted a systematic study of the crossover between the two regimes in the framework of the resonant-level model in order (1) to reveal the physical parameters governing the transition, (2) to expose its manifestations in linear transport, and (3) to track the evolution of the low-energy scale corresponding to the renormalized resonance width. In particular, focusing on strong electron-phonon coupling we find an extended regime where the bare electronic tunneling rate is large as compared to the phonon frequency and yet the physics is essentially that of the anti-adiabatic limit. The effective low-energy Hamiltonian in this regime is found to be the interacting resonant-level model, whose parameters we extract numerically.

Spin-charge separation in one-dimensional fermion systems beyond Luttinger liquid theory

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We develop a nonperturbative zero-temperature theory for the dynamic response functions of interacting one-dimensional spin-1/2 fermions. In contrast to the conventional Luttinger liquid theory, we take into account the nonlinearity of the fermion dispersion exactly. We calculate the power-law singularities of the spectral function and the charge- and spin-density structure factors for arbitrary momenta and interaction strengths. The exponents characterizing the singularities are functions of momenta and differ significantly from the predictions of the linear Luttinger liquid theory. We generalize the notion of the spin-charge separation to the nonlinear spectrum. This generalization leads to phenomenological relations between threshold exponents and the threshold energy.

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T100

Transport in and through correlated nanostructures: A density matrix renormalization group perspective

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Recent advances in simulating the time evolution of correlated electron systems led to progress in understanding transport properties of nano scale systems attached to leads. In this talk I provide an introduction on obtaining transport properties like the I/V characteristic or shot noise from the transient evolution of a charge imbalanced quench [1].

I provide results for dc-current [2] and noise [3,4] in the interacting resonant level model (IRLM) at its self dual point based on numerical simulations within the time dependent density matrix renormalization group approach (td-DMRG) and compare them with analytical results based on the thermodynamic Bethe ansatz. Next I discuss the transport properties of the Kondo model in strong coupling and the cross-over regime.

Then I extend the time dependent simulations to get access to the Full Counting Statistics (FCS) from time dependent simulations [4,5] via the cumulant generating function and provide results for the IRLM.

Finally I discuss the application of these techniques to light matter interaction at impurities coupled to one-dimensional wave guiding structures.

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Lasing and transport in a quantum dot-resonator circuit

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Circuit quantum electrodynamics (cQED) setups, where superconducting qubits are coupled to an electromagnetic circuit demonstrate many effects known from quantum optics, some of them with unprecedented quality. Moreover, the new parameter regime, i.e., strong coupling, low temperature, and single-qubit rather than many atoms, revealed qualitatively novel behavior. An example is lasing with a single superconducting qubit, where for strong coupling to the resonator, quantum noise influences the linewidth of the emission spectrum in a characteristic way [1].

We propose a different cQED setup, where a semiconductor double quantum dot is coupled to a high-Q (superconducting) resonator [2]. By driving a current through the dot system a population inversion in the dot levels can be created, which leads - within a narrow resonance window - to a lasing state in the resonator. In this semiconductor setup relaxation and decoherence processes are not weak. We analyze them in detail and show that the lasing state can be reached for realistic parameters.

In the proposed setup the lasing state correlates with the transport properties. On one hand, it allows probing the lasing state via a current measurement, which may be easier to perform in an experiment. On the other hand, the resulting narrow current peak opens perspective for applications of the setup for high resolution measurements. As an example we show that a small difference in the nuclear-spin induced Zeeman splitting between the two dots can be resolved with the help of the sharp lasing resonance condition. This allows for read-out and manipulations of spin qubits in doubly occupied double quantum dots.

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T102

Fundamental quantum effects in the laboratory

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This talk is devoted to quantitative analogies between fundamental quantum phenomena such as the Schwinger effect (i.e., electron-positron pair creation out of the vacuum induced by a strong electric field) and laboratory physics such as atoms in optical lattices. By studying these analogies, we may understand both scenarios better. On the one hand, laboratory realizations facilitate an experimental approach to the Schwinger effect which has not been observed yet. On the other hand, we may apply the theoretical machinery developed for this effect in order to understand condensed matter systems better. As an outlook, laboratory analogues of Hawking radiation and the Unruh effect are briefly discussed.

T103

Non-thermodynamic behavior for non-ergodic interactions: Violation of the 0th law

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The implication of the title should surprise no one. What may be surprising though is how easy it is to produce a quantum system with this feature; moreover, that system is one that is often used for the purpose of showing how systems equilibrate. The violation can be variously manifested; for example, bringing together two systems at the same temperature can cause one of them to cool, with no work necessary to maintain the disequilibrium.

T104

Driven electrons in strong laser fields

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High harmonic generation (HHG) is a fascinating phenomenon, wherein tunnel ionization of a molecule by an intense, low frequency laser field is followed by acceleration of the freed electron by the strong field and, upon reversal of the field direction, recombination of the revisiting electron with its parent core, with a consequent emission of harmonics of the incident frequency. Nonadiabatic alignment is a coherent process, wherein the interaction of a moderately intense pulse with the (permanent, induced, or transition) dipole moment of the molecule sequentially populates a broad rotational wavepacket. Provided that the pulse turn-off is short with respect to the system time scales, the phase relations among the rotational components guarantee that the wavepacket will align after the pulse, and will subsequently exhibit a coherent revival pattern. The combination of HHG with the nonadiabatic alignment concept has been the topic of rapidly growing activity during the past 6 years, remaining, however, the topic of controversy.

In the talk, I will first introduce HHG and laser alignment and next explore the information content of harmonic signals, their potential as a tool in molecular dynamics, and opportunities of controlling and utilizing the emitted light. In particular, I will illustrate that high harmonics generated from aligned molecules map the rotational coherences and contain signatures of the electronic continuum.

Optimization in stochastic thermodynamics: Efficiency of nano-machines (at maximum power)

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Stochastic thermodynamics [1] provides a framework for discussing the efficiency of small machines. For engines operating between heat baths of different temperature, efficiency at maximum power (EMP) is determined and shown to be different from the classical Curzon-Ahlborn result [2]. Under isothermal conditions work extraction is possible through measurement and feedback [3]. Molecular motors and future artificial nano-machines should operate isothermally and autonomously. Under such conditions, case studies have shown that EMP can depend sensitively on the parameter space available for the optimization [4]. Rather universal statements become possible within a general model implementing basic thermodynamic consistency [5]. In particular, it is shown that EMP is not bounded by 1/2 contrary to recent claims.

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T106

Diodic electric fields in NEMS/MEMS devices: Toward a solid-state second law challenge

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Nanoscale devices traditionally rely on external voltage sources for power, e.g., batteries, fuel cells, power supplies. In principle, however, sizable electric potentials and fields can be established between dissimilar metals and semiconductors via the dissimilar chemical potentials of their mobile charge carriers, as in pn diode junctions [1]. Diodic potentials and fields can be sustained across vacuum gaps indefinitely without power consumption, store usable capacitive energy, and can regenerate quickly if discharged. These fields have been invoked in challenges to the second law of thermodynamics based on MEMS and NEMS devices [2,3]. This paper presents experimental evidence for these vacuum diodic electric fields, and discusses their practical and thermodynamic implications.

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Mesic forces in quantum mechanics

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The equations of motion and the continuity equation have been derived from the relativistic Lagrangean density, corresponding to the motion of the electrically charged continuous substance with the flow velocity $\boldsymbol{v}$ in an external electrical field, diffusing simultaneously with osmotic velocity $\boldsymbol{u}$, the last obeying the diffusion law $\vec{u} = -D\nabla\mu/\mu$. The dependence of the osmotic velocity on the gradient of the mass density results in the appearance of mesic type forces and in a continuity equation with the right side, different from zero, expressing the density of internal rest mass sources. If identical continuity equation holds true at all points of the continuum, what is possible but for the flow velocity equal zero, than the equation of continuity represents the condition for steady, time independent states of the whole continuum volume. It has been proved, that the flow velocity – at least in the spherically symmetrical states – turns to zero automatically, owing to the fact, that the internal force densities in the electrically charge continuum compensate fully the external electrical force density. The equation of continuity, with $D = \hbar/2m$ and with the total electrical charge of the electron continuum around the proton e^-, represents the condition for steady bound states of the electron substance, equivalent to the Schrödinger equation, giving the same eigenfunctions and eigenvalues. A perturbation of a steady state by some additional external potential, either throughout the whole volume or in a part of it, leads to transient, time dependent states of short duration, during which the flow velocity as well as the mesic type forces, which are products of the velocity and the total time derivative of the mass density, differ from zero. The Newton law for volume elements situated at different points changes to $\vec{F} = \mathrm{d}(\mu\vec{v})/\mathrm{d}t = \mu\mathrm{d}\vec{v}/\mathrm{d}t + \vec{v}\mathrm{d}\mu/\mathrm{d}t$, where the second member represents the non zero mesic type forces between the establishment of next steady states. The duration of the transient periods are very short so that one may characterize them as jumps. Alas, the present experimental techniques do not permit to observe and to study the mesic forces directly. At the time being, their supposed existence may be supported only by the fact, that introducing them in the theory one gets a classical explanation of the observed steady states. At the end, it has been shown, that one obtains the continuity equation, from which the steady states may be derived, by simple algebraic operations from the Bohm equations, if one replaces his point electron by a charged electron continuum. Consequently, than also the quantum potential acquires a new interpretation.

T108

Bose Fermi mixture in a disordered one dimension potential: The Bose Fermi glass

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One-dimensional systems allow for a detailed study of the competing effects of disorder and interactions on the localization of a Fermi or Bose gas [1]. While non-interacting fermions are always localized in a random potential, a transition to a superconducting phase occurs for strong enough attractive interactions. Similarly, strong repulsive interactions will trigger the localization of a Bose gas [1,2]. During this talk, I will present the study of an interacting mixture of bosons and spinless fermions in a random potential. Superfluid correlations are enhanced by interspecies interactions, while the disordered potential tries to pin each component of the gas. Using renormalization group methods, supplemented by a variational calculation, we have found several localized or superfluid phases, including a new insulating phase, similar to the Bose glass, in which both species are coupled and localized [3]. We also computed the dynamical structure factor for typical parameters of various ultra-cold atoms experiments. Each phase exhibits its own signature, that could be probed in Bragg scattering experiments.

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Broadband waveguide quantum memory for entangled photons

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The implementation of quantum memory, i.e. a quantum interface between light and matter, is central to advanced applications of quantum information processing and communication [1]. Notably, quantum memories are key ingredients in quantum repeaters [2], which promise extending quantum communication beyond its current distance limit. Towards this end, quantum memories should have many features including the ability to store entangled states.

In this work we report the reversible transfer of photon-photon entanglement into entanglement between a photon and a collective atomic excitation in a rare-earth-ion-doped (RE) crystal [3] (see also [4]). We generate time-bin entangled photon-pairs with the photons of each pair at 795 and 1532 nm wavelength, suitable for low-loss transmission through free space and telecommunication fibres, respectively. The 1532 nm photons travel down an optical fibre while the 795 nm photons are sent into a thulium-doped lithium niobate waveguide cooled to 3 k, are absorbed by the TM ions, and recalled at 7 ns by means of a photon-echo protocol [5] based on an atomic frequency comb (AFC) [6]. The memory acceptance bandwidth has been tailored to 5 GHz, which matches the spectral width of the 795 nm photons.

The entanglement-preserving nature of our storage device is assessed through quantum state tomography before and after storage. Within statistical errors, we find a perfect mapping process. Additionally, we directly verify the non-local nature of the generated and stored quantum states by violating the CHSH bell inequality.

In light of future applications, the broadband and integrated features of our promising quantum storage device facilitate linking with commonly used, efficient sources of photons in bi- and multi-partite entangled states. This study paves the way for new explorations of fundamental and applied studies in quantum physics.

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T110

Quantum transport of cold atoms

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Cold atom devices permit the exploration of novel forms of quantum transport that are difficult or impossible to realize in traditional electron transport setups. Under the action of an external driving, long-term coherent atom motion can be quite sensitive to the initial switching conditions even in the presence of interactions [1]. If the driving violates space- and time-inversion symmetry simultaneously, then coherent motion of a Bose-Einstein condensate in a given direction can be induced [2], as has been recently observed [3]. For weak driving, this coherent quantum ratchet stems from the interference between first- and second-order processes, as revealed by precise analytical work [4]. A different scenario is that of a leaking condensate passing through an interface which separates regions of subsonic and supersonic flow. On the supersonic (normal) side of the event horizon, we find the bosonic analog of Andreev reflection in superconductors [5]. On the other hand, the analog of Hawking radiation is emitted into the subsonic side, even at zero temperature. We study a double barrier structure which is predicted to emit resonant, highly non-thermal Hawking radiation [6].

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Fast dynamics of molecular bridges

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This contribution addresses the problem of a proper description of fast dynamics of open quantum systems when initial conditions, quantum interferences and decoherence processes play important roles.

We treat fast dynamics in mesoscopic systems within Nonequlibrium Greens function (NGF) method formulated with initial condition [1]. We consider fast transients in a very simple structure which represents open quantum systems: a molecular bridge between two leads [2]. In this model the transient dynamics of electrons is induced by rapid changes in the coupling between the leads and the bridge. Transient response of electrons in the system depends on the joint effect of the initial state with correlations and of the driving external disturbances (represented here by the change in the coupling between the leads and the bridge) setting on at the finite initial time. If the initial state results from the previous history of the system, its role can be transformed onto the coherence effects between the transient and its antecedent. After the disturbances cease acting and the initial correlations die out, the process enters the non-equilibrium quasi-particle mode permitting a reduced description by a generalized master equation.

Formally these features are captured by the NGF technique within which we have introduced the partitioning in time method [3].

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T112

Realization of a sonic black hole analog in a Bose-Einstein condensate

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We have created an analog of a black hole in a Bose-Einstein condensate. In this sonic black hole, sound waves, rather than light waves, cannot escape the event horizon. A steplike potential accelerates the flow of the condensate to velocities which cross and exceed the speed of sound by an order of magnitude. The Landau critical velocity is therefore surpassed. The point where the flow velocity equals the speed of sound is the sonic event horizon. The effective gravity is determined from the profiles of the velocity and speed of sound. A simulation finds negative energy excitations, by means of Bragg spectroscopy.

Energy relaxation at the quantum Hall edge

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In this work we address recent experiment [1] of Altimiras and collaborators, where an electron distribution function at the quantum Hall (QH) edge at filling factor $\nu = 2$ has been measured with high precision. It has been reported that the energy of electrons injected into one of the two chiral edge channels with the help of a quantum point contact (QPC) is equally distributed between them, in agreement with earlier predictions, one being based on the Fermi gas approach [2] and the other utilizing the Luttinger liquid theory [3]. We predict that the physics of the energy relaxation process at the QH edge may in fact be more rich, providing the possibility for discriminating between two physical pictures in experiment. Namely, using the recently proposed non-equilibrium bosonization technique [4], we evaluate the electron distribution function and find that the initial "double-step" distribution created at a QPC evolves through several intermediate asymptotics, before reaching eventual equilibrium state. At short distances the distribution function is found to be strongly asymmetric due to non-Gaussian current noise effects. At larger distances, where noise becomes Gaussian, the distribution function acquires symmetric Lorentzian shape. Importantly, in the regime of low QPC transparencies T the width of the Lorentzian scales linearly with T, in striking difference with the equilibrium Fermi distribution, whose width scales as $\sqrt{T}$. Therefore, we propose to do measurements at low QPC transparencies.

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T114

Blockade and counterflow supercurrent in exciton-condensate Josephson junctions

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The terms superconductivity and superfluidity refer to dissipationless flow in charged and neutral systems, respectively. Superfluid exciton condensates, in which macroscopic phase coherence is established among pairs composed of electrons and holes in different bands, have been realized only recently. Signatures of exciton condensation have been reported in quantum Hall bilayers, in which electrons and holes are located in two separate two-dimensional electron layers [1]. When the two layers of a bilayer exciton condensate (EC) are contacted separately, it can exhibit remarkable transport anomalies associated with its neutral supercurrents. These properties provide an appealing platform for spectacular electrical effects in EC-superconductor hybrid systems in which the charged superconducting order parameter interfaces with the neutral EC order parameter. In this work we demonstrate that when two superconducting circuits are coupled through a bilayer EC, the superflow in both layers is drastically altered. If the same phase bias is applied to both junctions, no Josephson current can flow through the system, a phenomenon we refer to as exciton blockade. When a phase bias is applied to only one layer, on the other hand, it induces a superdrag counterflow supercurrent of the same magnitude in the unbiased layer.

In our calculations we assume that the superconducting electrodes in each layer are separated by a distance L much larger than the exciton coherence length, and an independent phase bias is applied to the top and bottom contacts. In the presence of these biases, Josephson currents flow through the double layer. Because the EC is gapped, only dissipationless counterflow can contribute to the Josephson current when L is long. We have considered both the short- and long-junction regimes, with respect to the superconducting coherence length, and the effect of a finite temperature.

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A phonon laser

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Red-detuned laser pumping of an atomic resonance will cool the motion of an ion or atom. The complementary regime of blue-detuned pumping is far less explored and widely thought of as a regime of heating. Theory and experiment instead show that stimulated emission of centre-of-mass phonons occurs, providing saturable amplification of the motion. A threshold for transition from thermal to coherent oscillating motion has been observed, thus establishing this system as a mechanical analogue to an optical laser: a phonon laser.

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T116

Quantum interference in molecular junctions

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In mesoscopic structures, such as Aharanov-Bohm rings, destructive (constructive) electron interference leads to a decrease (increase) in sample conductance. Molecules are perfect candidates to study similar quantum effects at higher temperatures, since their energy level spacing is large ($\sim$ eV). Specifically, for junctions containing cross-conjugated molecules, destructive interference is anticipated at certain electron energies. Here, we report direct evidence for interference effects in molecular junctions at room temperature. For this, we first synthesized a family of (di)thiolated organic molecules. The molecules are different in their central ring only, but have different conjugation nevertheless (cross-conjugation vs. linear conjugation). Subsequently, the molecules were self-assembled in a compact monolayer (SAM) on a gold-coated Si-substrate. Charge transport measurements were done by making use of conductive atomic force microscopy (c-AFM). Our results show a profound difference between the cross-conjugated anthraquinone derivatives and the linearly conjugated molecules, both in conductance values and in actual dI/dV-curves. Moreover, our data for the cross-conjugated molecules are fully consistent with destructive interference via orbital pathways, as confirmed by extensive transport calculations (DFT+Σ-approach). All in all, our study demonstrates a fundamentally new quantum phenomenon in molecular charge transport. Moreover, it opens the road for a new type of molecular switches. These could be based on either chemical or electrostatic control of quantum interference.

Vibronic effects in transient behavior of molecular bridges

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Sudden changes in the connectivity of a molecular bridge between two metallic leads result in a complex transient behavior in the local charge and current state of the system. This in turn induces a reconstruction of the local vibronic structure caused by the electron-local vibron coupling. This rapid process leads to an effective initial condition for the ensuing kinetic regime.To describe the transient process for the weak to intermediate electron-vibron coupling we employ the dynamical Tamm-Dankoff method viewed as as a cascade multi-phonon expansion. The self-consistent local oscillations are damped by the leads and a weakly coupled phonon bath.

T118

TDDFT and Green's function dynamics for strongly correlated model systems

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We discuss two approaches to the nonequilibrium dynamics of strongly correlated model systems (Hubbard model), namely Time Dependent Density Functional Theory (TDDFT) and the nonequilibrium Green's function (NEG) method via Many-Body Perturbation Theory. Different approximations for the exchange correlation potential of TDDFT and for the NEG self-energy will be presented, and comparisons to exact solutions performed. Results from specific applications will be also shown, along with a brief mention to work in progress.

Towards hybrid quantum circuits: Strong coupling of a spin ensemble to a superconducting resonator

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It seems appealing to combine artificial atoms like supeconducting qubits and natural quantum systems in ‘hybrid’ quantum circuits that would exhibit long coherence times while allowing rapid quantum state manipulation. The two types of object would be strongly coupled to a superconducting resonator used as a quantum bus. We report here [1] a first steps towards this architecture: the realization of a quantum circuit in which an ensemble of electronic spins is coupled to a frequency tunable superconducting resonator. The spins are nitrogen-vacancy centers in a diamond crystal. The achievement of strong coupling is manifested by the appearance of a vacuum Rabi splitting in the transmission spectrum of the resonator when its frequency is tuned through the nitrogen-vacancy center electron spin resonance. We also observe in the time-domain the exchange of a coherent state between the resonator and the spins.

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T120

Anomalously elastic, intermediate phase in randomly layered superfluids, superconductors, and planar magnets

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We show that layered quenched randomness in planar magnets leads to an unusual intermediate phase between the conventional ferromagnetic low-temperature and paramagnetic high-temperature phases. In this intermediate phase, which is part of the Griffiths region, the spin-wave stiffness perpendicular to the random layers displays anomalous scaling behavior, with a continuously variable anomalous exponent, while the magnetization and the stiffness parallel to the layers both remain finite. Analogous results hold for superfluids and superconductors. We study the two phase transitions into the anomalous elastic phase, and we discuss the universality of these results, and implications of finite sample size as well as possible experiments.

The 0.7-anomaly in quantum point contacts: Evidence for a Nozières' Fermi liquid

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We present a microscopic theory for the 0.7-anomaly in the conductance of a quantum point contact, based on a one-dimensional model with a local interaction and a smooth potential barrier. Using the functional renormalization group to calculate the conductance $G(V_g, B)$ as function of gate voltage and magnetic field at zero temperature, we find qualitative agreement with previous and new experiments. Similar calculations for a one-dimensional quantum dot show that the low-energy phenomelogy of the 0.7-anomaly is related to that of the Kondo effect in quantum dots, in that both exhibit interaction-enhanced spin-fluctuations in regions of low charge density that can be described using a Fermi liquid theory a la Nozières. This observation leads to the prediction that the ratio T^*/B^* should be independent of gate voltage for both the Kondo effect and the 0.7-anomaly, where T^* and B^* are the characteristic temperature and magnetic field scales that govern the leading dependence of the conductance on temperature and magnetic field, respectively. We present new experimental data for the 0.7-anomaly that confirm this prediction and hence provide support for the Fermi liquid description proposed here.

T122

Coherent tunneling and canyon of current suppression in quantum dots

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Recently, a canyon of conductance suppression in a semiconductor nanowire quantum dot was reported [1]. Here a distinct line of vanishing conductance crosses both the lines of direct tunneling as well as the Coulomb blockade region in the conventional conductance spectrum. This effect is attributed to the crossing of levels with equal spin and can be well reproduced within the second order von Neumann formalism [2] for transport developed by some of us earlier. The general scenario contains the previously predicted vanishing conduction at the electron-hole symmetry and the associated correlation-induced resonance [3] as limiting cases.

Here we demonstrate in detail how this current suppression arises in a general two-level system with equal spin, which is attached to two leads [4]. It turns out that the existence of this canyon occurs over a wide parameter range and is clearly visible both for small and finite bias. Using different approaches such as Breit-Wigner transmission for noninteracting states and a Schrieffer-Wolff transformation for the strongly interacting case close to the electron-hole symmetry point, we elucidate the origin of conductance suppression. For larger bias, on the other hand, the current suppression can be related to blockade effects in the spirit of [5].

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Multi-order interference and Born's rule

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R. D. Sorkin [1] investigated the possibility that quantum mechanics might be formulated as a generalized measure theory. Born's rule stipulates that quantum mechanical probabilities are absolute squares of complex amplitudes. This results in the well-known phenomenon of interference and constitutes a violation of a sum rule for the additivity of probabilities of mutually exclusive events. One can imagine a yet more general theory by assuming that it violates the next higher sum rule about the additivity of probabilities of three mutually exclusive possibilities. Standard quantum mechanics does obey this second sum rule. It has been shown that a violation of the second sum rule might allow computation that is more powerful than quantum computation.

Previously, we experimentally tested the validity of the second sum rule by measuring the interference patterns produced by three slits and all the possible combinations of these slits being open or closed. We use either attenuated laser light or a heralded single photon source combined with single photon counting to confirm the particle character of the measured light. Within our experimental accuracy and Born's rule is vindicated and the second sum rule appears to be obeyed [2,3].

In order to improve the experimental accuracy we have built a three-path interferometer using a diffractive beam-splitter. This arrangement allows us to use regular shutters in the three beam paths, while being phase-stable enough to measure for long periods of time with much higher throughput than in the triple slit experiment. We will present the latest limit on multi-order interference as well as detector nonlinearity calibration measurements and an estimation of the ultimate limit one may achieve with this method using a range of sources and detectors.

This work has been supported in part by the Canadian Institute for Advanced Research (CIFAR) and the Foundational Questions Institute (FQXi).

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T124

Nonlinear quantum transport and noise statistics

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Quantum Brownian motion of a particle or charge in a corrugated tilted potential is one of the basic subjects of nonequilibrium quantum statistical mechanics and is a key model for a multitude of nonlinear quantum transport phenomena in condensed matter physics. In this talk I review the respective imaginary-time Coulomb gas and real-time Keldysh methods. The former is advantageous in analytical approaches. It requires however subtle analytical continuation and firm handling of subtractions, and is limited to the transport current. The real-time method is essential in the field of full counting statistics. Recent developments in these topics are presented and advances in exact analytic solutions covering the entire range from weak to strong tunneling are discussed.

Simulating quantum systems in biology, chemistry and physics

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In principle, it is possible to model any physical system exactly using quantum mechanics; in practice, it quickly becomes infeasible. Recognising this, Richard Feynman suggested that quantum systems be used to model quantum problems [1]. For example, the fundamental problem faced in quantum chemistry is the calculation of molecular properties, which are of practical importance in fields ranging from materials science to biochemistry. Within chemical precision, the total energy of a molecule as well as most other properties, can be calculated by solving the Schrodinger equation. However, the computational resources required to obtain exact solutions on a conventional computer generally increase exponentially with the number of atoms involved [1, 2]. In the late 1990's an efficient algorithm was proposed to enable a quantum processor to calculate molecular energies using resources that increase only polynomially in the molecular size [2–4]. Despite the many different physical architectures that have been explored experimentally since that time—including ions, atoms, superconducting circuits, and photons—this appealing algorithm has not been demonstrated to date.

Here we take advantage of recent advances in photonic quantum computing [5] to present an optical implementation of the smallest quantum chemistry problem: obtaining the energies of H2, the hydrogen molecule, in a minimal basis [6]. We perform a key algorithmic step—the iterative phase estimation algorithm [7–10]—in full, achieving a high level of precision and robustness to error. We implement other algorithmic steps with assistance from a classical computer, explain how this non-scalable approach could be avoided, and provide new theoretical results which lay the foundations for the next generation of simulation experiments.

We also report on our recent results in simulating quantum systems in material science—phase transitions in topological insulators—and in biology—light-harvesting molecules in photosynthesis. Together this body of work represents early experimental progress towards the long term goal of exploiting quantum information to speed up calculations in biology, chemistry and physics.

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T126

Biology: A cosmological constraint?

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The origin of life can be regarded as an anthropic constraint on the nature of the Universe, and any valid model of the Universe must be consistent with this constraint. The emergence of prescriptive information leading to a protogene system capable of evolving into DNA-based life is argued to be a unique event. The cybernetic nature of life does not plausibly admit of more than a single origin by processes that are still to be fully understood. Once originated, however, its spread from a single source of origin is best achieved by the action of radiation pressure on metallic whiskers onto which viable bacteria are attached. At speeds of 10^3 km/s such particles could diffuse through a distance of 10 Mpc in timescales of 10^9 yr. With a cosmological distribution of suitable replicating sites (eg planets and comets) [1] the early universe could become efficiently colonised in this way, with the expansion of the universe carrying through the legacy of life to the present epoch. The detection of organic molecules (eg polycyclic aromatic hydrocarbon PAH signatures) at high redshifts are plausibly explained as representing degradation products of biology.

The prediction [2] and observation [3] that the dark matter of galaxies is earth-mass primordial gas planets in trillion planet clumps is strong support for an early origin of life. By hydrogravitational dynamics HGD cosmology all stars are formed by planet mergers. Overfeeding the first stars with planets leads to supernovae and first life chemical production. Reducing hot hydrogen atmospheres of the planets converts oxides of iron to metal and water. Condensation of the first oceans at water critical temperature 647 K of the merging planets thus creates a mixing primordial soup in which first life can form and be widely distributed on cosmic scales [4].

Just as HGD cosmology supports Hoyle-Wickramasinghe cometary panspermia, the indicated biological big bang at 2 million years supports HGD cosmology. The extreme complexity of DNA chemistry, widely spread in cosmic space-time, is quite impossible following the concordance ΛCDMHC scenario.

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Quantum jumps in non-thermal-equilibrium systems: How far beyond Einstein do we need to go?

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The quantitative dynamics of open quantum systems was first studied by Einstein, who introduced a model of stimulated and spontaneous jumps between Bohr's stationary atomic states. Here, the system (a singe atom) is in thermal equilibrium with a bath and its steady state is a Boltzmann-weighted mixture of energy eigenstates. The quantum jumps can be associated with energy transfer to and from the bath, and continuous monitoring of the bath would therefore allow one to identify which particular energy eigenstate the atom occupies at any particular time. Approximating the equilibrium state as a mixture of a finite number D of energy eigenstates, it is clear that a K-state classical memory with K = D is clearly sufficient to keep track of the state of this quantum system (i.e. to know the exact pure state it is in).

For the dynamics of open quantum system not in thermal equilibrium, the situation is much more complex. For any open quantum system obeying a Markovian master equation it is possible in principle to monitor the environment so that the system is in a pure state, this state will not in general be a stationary state. This means that storing a string of jumping times (each a real number), or the state itself (D-2 real numbers), might be required in order to keep track of the state of the system. Thus it is not at all obvious that one can follow the exact dynamics of an open quantum system with a finite classical memory, even in equilibrium (i.e. a non-thermal equilibrium in general, reached in the long-time limit of any master equation with a unique steady-state).

We address this question for quDits in general terms, and the qubit in particular [1]. We argue that, by allowing for adaptive monitoring, one would expect to be able to track a quDit using a K-state classical memory as long as K > $(D\text{-}1)^2$. For a qubit we show explicitly that there always exists a monitoring scheme that ensures that the qubit jumps between only two possible states. Unlike Einsteinian dynamics for a two-level atom, the two states are non-orthogonal, and the monitoring of the qubit's environment must be adaptive, controlled by the classical bit that stores the state of the qubit. We determine the condition for stability of these trajectories and show that it is always satisfied for a family of master equations describing resonance fluorescence [2].

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T128

Persistent current noise and electron-electron interactions

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We analyze fluctuations of persistent current (PC) produced by a charged quantum particle moving in a ring and interacting with a dissipative environment formed by diffusive electron gas. We demonstrate that in the presence of interactions such PC fluctuations persist down to zero temperature. In the case of weak interactions and/or sufficiently small values of the ring radius R PC noise remains coherent and can be tuned by external magnetic flux piercing the ring. In the opposite limit of strong interactions and/or large values of R fluctuations in the electronic bath strongly suppress quantum coherence of the particle down to zero temperature and induce incoherent flux-independent current noise in the ring which persists even at zero external flux when the average PC is absent.

Recent experiments with photons: Testing the foundations of quantum physics and developing new tools for quantum information

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Tests of the foundations of quantum physics have been crucial stepping stones for the development of the field of quantum information science. In the talk I will discuss two recent photonic tests. One experiment [1] closed a specific class of the freedom-of-choice loophole. That loophole suggests that the choice of measurement parameter in a Bell test is influenced by the emission event of the photons from the source. It was ruled out by having the decision which polarization to measure space-like separated from the emission. The experiment itself was performed at the European Northern Observatory on the Canary Islands of Tenerife and La Palma. The experiments violate a Bell Inequality by about 20 standard deviations. The fast feed-forward technology used in the experiment is also crucial for measurement-based quantum computation procedures.

Independent of the locality assumption, the Kochen-Specker theorem allows to investigate fundamental questions for individual systems. Recently Klyachko et al [2] proposed a strategy to test whether the predictions of quantum physics can be explained by underlying joint probability distributions. Both the original Kochen-Specker idea and the Klyachko proposal use the quantum predictions for spin-1 systems, i.e. qutrits. In the recent experiment in Vienna we realize the qutrits by coherent superpositions of three modes of a single photon. The experiment confirms the quantum predictions [3] and rules out that the measurement result may be understood by and underlying (classical) probability distributions by about 80 standard deviations. This confirms the nonclassicality of a system which does not even in principle allow entanglement between different internal or external variables.

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T130

Engineered dissipation for quantum information and many body physics

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We discuss engineering of open system dynamics in systems of cold atoms and ions. We are interested in controlled coupling to an environment both as a tool for quantum information processing and quantum simulation, as wells as in the context of non-equilibrium condensed matter physics. Our discussion will start with a description of an open system Rydberg quantum simulator [1], and we present a related experiment with cold trapped ions demonstrating entangled state preparation by dissipation [2]. We then present examples of d-wave pairing induced by dissipation [3], and a dissipative version of Majorana edge states [4].

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Invited Posters

Quasiparticle agglomerates in particle-hole conjugate of Read-Rezayi states

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We will investigate the disorder dominated phases of particle-hole conjugate of Read Rezayi states [1,2,3,4]. We will discuss the dominant excitations for these models describing fractional quantum Hall states for $\nu = 2/(k+2)$ taking in account non-universal renormalizations effects [5]. We will find the dominant charges observed at low and higher energies. The discussion is presented in analogy with the crossover phenomena observed and predicted for fractional quantum Hall states in the Jain sequence [6,7,8].

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I2

Superconducting proximity effect in hybrid quantum dots revealed by noise

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Current fluctuations in a nanoscale conductor yield more information than the average current [1]. Several theoretical approaches have been developed to determine the complete statistics of the charge transport, the full counting statistics (FCS), both in non-interacting and in interacting nano-scale systems [2]. Interestingly it is nowadays possible to measure high-order moments and test the predictions. In this perspective the hybrid superconducting-normal structures with quantum dots offer the unique possibility to study the interplay of superconducting correlations, strong Coulomb interaction, quantum fluctuations and non-equilibrium physics as a function of tunable system parameters. Subgap transport in these structures is mediated by Andreev reflection [3,4] and it has been studied extensively both theoretically and experimentally. Here we analyze the FCS of charge transport through a quantum dot tunnel-coupled to one normal and one superconducting lead with a large superconducting gap [5]. As function of the level detuning, we predict a crossover from a regime with strong superconducting correlations in the quantum dot to a regime in which the proximity effect on the quantum dot is suppressed. We analyze the current fluctuations of this crossover in the shot-noise regime. In particular, we predict that the full counting statistics changes from Poissonian with charge 2e, typical for Cooper pairs, to Poissonian with charge e, when the superconducting proximity effect is present. This counter-intuitive result shows that that the superconducting proximity effect on the dot can be revealed by a measurement of current fluctuations, rather than the current.

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Higgs-induced bound states of heavy particles and baryogenesis. Gravitational bound states and resonances in the black hole limit

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1. Higgs-induced bound states of heavy particles and baryogenesis: We consider energy levels of t-quarks and W,Z-bosons captured to the bags with strongly depleted Higgs vacuum expectation value. Such bags are formed after Big Bang and stabilised by captured heavy particles. Barion number violation happened predominately inside such bags. If there exist new generation of heavy fermions, strong binding can make states with mass 1-2 TeV which does not increase with the fermion mass (which vanishes inside the zero-Higgs bag). Such states may be observed at LHC.

2. Dense spectrum of resonances and particle capture in a near black-hole limit: Quantum particle in the gravitational field of massive body of radius R which slightly exceeds Schwarzschild radius r_s, possesses a dense spectrum of narrow resonances with lifetimes and density which tend to infinity in the black hole limit. The energy averaged (optical) cross section of the particle capture to this resonances reproduces Unruh's black hole capture cross section. Thus, a non-singular static metric may have black hole properties without actual formation of a black hole.

I4

Quantum-like models of decision making

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We present the quantum-like paradigm for biology, cognitive psychology, and modeling of brain's functioning. By this paradigm contextuality of biological processes induces violation of laws of classical (Kolmogorovian) probability, starting with the fundamental law of total probability. New nonclassical models have to be used for mathematical modeling of contextual phenomena. Quantum probability was discovered as the first non-Kolmogorovian probabilistic model. Therefore it is natural to apply it to a wide range of problems. However, quantum physics should be sharply distinguished from quantum mathematics. In general, e.g., in biology or psychology, the usage of quantum mathematics and its generalizations has nothing to do with quantum physical processes in biological organisms. Models based on noncommutative probabilistic theories are called quantum-like. In this talk we discuss applications of quantum-like models in biology and psychology.

In psychology we present a model of brain's functioning based on quantum-like representation of information. The process of decision making is described by master equation as the process of decoherence of a pure quantum-like mental state (superposition of possible decisions) coupled to mental bath (memory).

In molecular biology we study quantum-like interference of probabilities induced by the glucose effect on *E. coli* (*Escherichia coli*) growth; similar effect was found for tooth cells differentiation. This study is a first step towards quantum-like models of gene regulation.

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Optimal tuning of solid state quantum gates: A universal two-qubit gate

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We present a general route to reduce inhomogeneous broadening in nanodevices due to 1/f noise [1]. We apply this method to a universal two-qubit gate and demonstrate that for selected optimal couplings, a high-efficient gate can be implemented even in the presence of 1/f noise. Entanglement degradation due to interplay of 1/f and quantum noise is quantified via the concurrence. A charge-phase square-root-i-SWAP gate for spectra extrapolated from single qubit experiments is analyzed. In addition, we demonstrate that the approach applies also to circuit-QED architectures of universal two-qubit gates.

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I6

Pulsed quantum optomechanics: Remote state preparation and quantum state tomography

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Experiments that probe quantum mechanical phenomena, such as entanglement and quantum superpositions, are currently restricted to systems on atomic scales. It is assumed that for large systems quantum behavior is masked by decoherence or that quantum mechanical laws may even require modification. Despite some substantial experimental advances, probing this regime remains extremely challenging. The novel field of opto-mechanics, where a mechanical oscillator interacts with light via radiation pressure, offers a rich and promising avenue for the exploration of quantum mechanical behavior in a macroscopic regime. However, quantum state preparation and especially quantum state reconstruction of mechanical oscillators remains a significant challenge, mainly due to insufficient light-matter coupling and due to thermal noise. Here we propose a scheme to realize quantum state tomography, squeezing and state purification of a mechanical resonator using short optical pulses.

The scheme presented allows observation of mechanical quantum features despite preparation from a thermal state and is shown to be experimentally feasible. We show that the same experimental tools used for quantum state tomography can also be used for quantum state engineering and state purification, which thus provides a complete experimental framework. Our scheme does not require "cooling via damping" and can be performed within a single mechanical cycle, thus significantly relaxing the technical requirements to minimize thermal contributions from the environment. Our framework thus provides a promising means to explore the quantum nature of massive mechanical oscillators, and can be readily applied to other systems such as trapped ions.

Time-dependent theory of non-linear response and current fluctuations

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A general non-linear response theory is derived for an arbitrary time-dependent Hamiltonian, not necessarily obeying time-reversal symmetry. We consider the application of this theory to a multi-terminal mesoscopic system with arbitrary interactions and time-dependent voltages. This allows us to obtain a generalized Kubo type formula. We derive a microscopic expression for the differential conductance matrix which preserves current conservation and gauge invariance. We exploit this result to show that the asymmetric part of the current fluctuation matrix obeys a generalized Fluctuation-Dissipation Theorem. In the stationary regime, this theorem provides a common explanation for the asymmetry of the excess noise with respect to positive and negative frequencies that has been obtained in several systems, as a consequence of non-linearity. It also explains the origin of the unexpected negative sign of the excess noise. Finally, we apply these general results to the case of a tunnel junction and obtain a non-perturbative out-of-equilibrium link between conductance and current fluctuations. We also derive a universal property of the finite frequency noise in the perturbative regime.

I8

Spectral signatures of Bose–Einstein condensation of excitons in cuprous oxide

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Excitons in excited semiconductors have been promising candidates for the observation of Bose–Einstein condensation (BEC) for several decades. At present, cuprous oxide (Cu_2O) is in the focus of experimental efforts due to the large binding energy and long lifetime of the exciton states. In order to obtain sufficiently high particle densities, entrapment by an external potential is an approved method.

So far, the theoretical description of excitons in potential traps has been carried out mostly using a model of ideal bosons. Concepts for the inclusion of the interaction are well known from the theory of atomic condensates [1, 2], and first applications to excitons exist, too [3]. Recent investigations in the framework of a mean-field formalism in local density approximation have shown distinct signatures of a condensate in the decay luminescence spectrum of the non-condensed excitons already in the singlecomponent (paraexciton) case [4]. Moreover, for interacting para- and orthoexcitons, additional phase separation effects are observed at the onset of BEC [5, 6].

It is the aim of this contribution to analyze signatures of a possible Bose–Einstein condensate. The system under consideration is a multi-component gas of interacting para- and orthoexcitons in a Hertzian trap. We show results for the density distributions as well as the spatially resolved luminescence spectra of the individual components and discuss occurring signatures of BEC. Special attention is paid to the comparison between the cases of (i) a completely dark condensate (as theoretically predicted in the quasi-homogeneous case [4]) and (ii) a very weakly luminescing condensate (as suggested by several physical arguments).

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Degree of ionization of electron-hole pairs in bulk GaAs and GaAs-GaAlAs quantum wells

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The Mott transition of excitons in a semiconductor, i.e., their breakup with increasing carrier density, is in principle well understood as a consequence of many-particle effects. In [1] a consistent quantum statistical theory of the ionization equilibrium between bound (excitons) and non-bound electron-hole pairs was presented. It was shown that, while the position of the exciton stays widely unchanged with increasing excitation, the exciton peak is broadened and vanishes due to band gap shrinkage. The subtle density dependence of the exciton position, however, has an essential influence on the Mott density.

In this contribution we apply the approach presented in [1] to GaAs-GaAlAs quantum wells. In such heterostructures the transition from a 3-dimensional to quasi-two-dimensional system can be investigated by varying the well width. We compare our results with those from recent experiments [2], where we have investigated the resonance fluorescence for localized exciton states in single quantum wells with a width of 9.9 nm/19.8 nm, corresponding to an effective dimension of d = 2.35/2.53. Moreover, for comparison our theoretical calculations are extended to bulk GaAs (d = 3). In the experiments, increasing the number of injected carriers, we first observe a strong decrease of the emission, which turns into an increase for higher excitation. We interprete this behavior as the Mott transition of excitons. The emission, initially coming from excitons, changes to that of an ionized electron-hole plasma.

Our theoretical approach is based on the one hand on a self-consistent calculation of one-particle carrier self-energies in quasi-particle approximation including the dynamical screening of the Coulomb interaction. The results are used to investigate the chemical equilibrium between excitons and non-bound electron-hole pairs, calculating the degree of ionization [1] in dependence on temperature and density of carriers. On the other hand, this thermodynamic treatment is completed by an investigation of the spectral behavior of the exciton by solving the semiconductor Bloch equations. Dynamical screening, renormalized quasi-particle energies and the self-consistently determined chemical potentials of carriers are included in our calculations. The theoretical results for quantum wells are in good agreement with those from the experiments. Increasing the excitation, we find the Mott density around $2 \cdot 10^{10}$ cm^{-2} for temperatures up to 100 K. We show that the findings correspond to results we get for bulk GaAs as a related three-dimensional system.

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Posters

Thermodynamic basis of martensitic transformation in copper based shape memory alloys

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Shape memory effect is an unusual property exhibited by certain alloy systems, shape memory alloys. Shape memory behaviour of materials is based on a solid state phase transformation, martensitic transition, which occurs with the cooperative movements of atoms in the alloy. Martensitic transformation is a diffusionless first order phase transition and occurs with cooling the material from high temperature or applying a stress to materials. Product martensite inherits the order of high temperature matrix phase due to this property, but distances between the atoms change, because this transition causes to the structural changes in atomic scale. Copper based alloys exhibit this property in beta -phase field which have the disordered bcc structure, and undergo two types of ordered reactions called premartensitic transitions on cooling. The first transition is a first-nearest neighbour (nn) ordering reaction and results in a B2-type superlattice. However, bcc to DO3 transition induces the next-nearest neighbour (nnn) ordering reaction. The first transition is second order, latter is also first order.

Martensitic transition occurs mainly in two steps. First step is Bain distortion with which an fct unit cell turns into an fcc unit cell, and at the second step, two or more lattice invariant shears occur on a 110-type plane of austenite matrix which is basal plane or stacking plane for martensite. These shears causes to the formation of unusual layered structures in material. Copper based shape memory alloys are metastabe; they are very sensitive to heat treatment and strongly affected by quenching and ageing treatments in martensitic condition. This effect causes to the changes in material characteristics and is known as stabilization of martensite and leads to the rearrangement of atoms in the alloy. This rearrangement occurs as an order-disorder transition which has diffusive character. The possibility to have diffusion controlled atom redistributions in the martensite after the transformation means to have additional possibilities to lower the Gibbs energy. Therefore, changes in the martensite structure occur in crystallographic manner. Mainly two factors control phase transitions and the changes which occur by diffusion, a thermodynamic and a kinetic one. The thermodynamic driving force for redistribution is determined by the lowering of the Gibbs energy.

The above mentioned properties are investigated by means of DSC technique, and x-ray end electron diffraction techniques on two copper based ternary alloys.

P2

Experimental estimate of a classicality witness via a single observable

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The potential presence of quantum correlations in separable states opened exciting new possibilities regarding its use as a resource in quantum information science. Quantifying such quantum correlations involves the complete knowledge of the system's state and numerical optimization procedures. Thus it is natural to looking for observable witnesses (refered here as classicality witnesses) which are obtained with an abridged number of measurements and still indicate the nature of correlations in a system. Here we show theoretically and experimentally that a recently proposed classicality witness can be estimated via a single observable. Upper and lower bounds for the classicality witness can be obtained through projection onto Bell states.

P3

Spin waves in magnetic-semiconductor superlattices

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Magnetic semiconductors are hybrid systems in which magnetic impurities couple indirectly via a bath of itinerant spin carriers. The density of magnetic impurities can be modulated along the growth direction of the semiconductor to build periodic magnetic structures at the nanoscale, where quantum effects are relevant. Here, we present a theory of collective spin excitations in low-dimensional magnetic-semiconductor superlattices with a view to spin-wave band design for magnonics (an emerging research field which explores spin waves, i.e. magnons, for information processing) and the possible development of interfaces with (spin)electronic systems.

P4

Quantum chaotic system as a model of decohering environment

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Decoherence, which is caused due to the interaction of a quantum system with its environment, leads to the loss of quantumness of the system [1]. This phenomenon is believed to be responsible for the quantum-classical transition, and it is also a great obstacle for the realization of quantum computer [2]. In decoherence studies, the environment is generally modeled by many-body systems, e.g., many harmonic oscillators in thermal equilibrium (Feynman-Vernon/Caldeira-Leggett model), spin-boson model, etc [3-4]. In this work [5], we study single particle quantum chaotic system as a model of decohering environment. We explore how this simple deterministic model can reproduce the decohering effects of many-body environment. Our results show that, like the many-body environment, the quantum chaotic system is an efficient decoherer, and it can generate entanglement between two qubits which have no direct interaction.

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A simple trapped-ion architecture for high-fidelity Toffoli gates

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In the quest for scalability of a quantum computing device, the role played by many-qubit gates is quite central. We discuss a simple architecture for a quantum Toffoli gate implemented using three trapped ions [1]. Our scheme exploits an enlarged computational space consisting of three-level particles and an ancillary phononic mode [2, 3]. While information is encoded only in two electronic states of each ion, their third levels are used as convenient working spaces, similarly to the phononic ancilla. Such enlarged computational space allows a considerable reduction in the number of operations used in order to implement the three-qubit gate. In fact, by adhering as much as possible to the parameters and working conditions of a single experimental setting, we show that our proposal requires roughly 44% of the operations needed in the seminal proof of principle provided by Monz [4]. The gate, which in principle can be implemented with a single laser-induced operation, is effective under rather general conditions and is strikingly robust (within any experimentally realistic range of values) against dephasing, heating and random fluctuations of the Hamiltonian parameters. We provide a full characterization of the unitary and noise-affected gate using three-qubit quantum process tomography [5].

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P6

Efficient photonic crystal cavity - waveguide couplers

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Directional couplers with cavity axes non-parallel to waveguides axes have recently been studied by Kim et al [1] for coupling the hexapole modes of single hole defect cavities and by Shinya et al for coupling L3 and L4 cavities [2]. In this paper, we investigate the coupling of linear three hole cavities (L3) [3] into PC waveguide. we choose the L3 cavities for their high quality factor (Q) to mode volume (V) ratio and good matching between cavity and waveguide field patterns, which improves in plane coupling efficiency [4,5]. The systems are designed to increase the overlap between the evanescent cavity field and the waveguide mode, and to operate in the linear dispersion region of the waveguide. Our simulations indicate increased coupling when the cavity is tilted 60° with respect to the waveguide axis. The transmission spectra and the field patterms are obtained by using Fullwave which is a commercially available finite-difference time-domain code. To test the validity of our approach, we compare the coupling parameters for the tilted cavity configuration to the standard approach where the cavity and the waveguide share the same axis (straight cavity configuration). It can be noted that the quality factor is lower for the tilted than the straight configuration. this result is a consequence of higher coupling for tilted cavities.

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Refractive index sensor based on photonic crystal waveguide structure

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Photonic crystals (PCs) have achieved a lot of research significance due to their projected applications. Their use as sensors [1,2] is enabled due to their well-defined physical properties such as reflectance/transmittance, superior levels of sensitivity resulting in precise detection limits. During the last three decades, optical sensor elements for refractive index (RI) measurement have been subject to research interest, and still today new technologies are suggested. The application of RI sensors includes measurement of parameters like temperature, humidity, chemical composition, detection of DNA, proteins, cells and bacteria. Recently, a wide range of PC sensing devices has been presented in the literature [3]. PC waveguide is one class of PC devices that has been demonstrated for RI measurements [4,5]. In this paper, we propose an ultracompact RI sensor based on single line photonic crystal waveguide structure. The transmission spectrums of the sensor with different ambiant refractive indices are calculated. The calculation results shows that a change in ambiant RI is apparent; the sensitivity of the sensor is achieved. The shape of the air holes localized at each side of the line defect is optimized to realize high sensitivity, wide measurement range and improved transmission.

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P8

Observation of topological phases in photonic quantum walks

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A striking features of quantum mechanics is the appearance of new phases of matter whose origins are rooted in topology. Such phases have attracted significant attention in recent times beginning with the observation of the quantum Hall effect [1], and later with the discovery of topological insulators. In this paper we investigate the topological properties of an entirely artificial system; a one-dimensional photonic quantum walk [2]. The quantum walk by its nature is dynamic and represents a periodic drive of a quantum system, through this we reveal an entirely new topological phenomenon: the existence of a topologically-protected pair of localized states that has no analogue in static, i.e. non-driven, systems.

To reveal the topological properties of the quantum walk we implement a variation of the standard protocol [3]; the split-step protocol [4]. The symmetry properties of the Hamiltonian that describe the split-step quantum walk define the class of topological phases that it can exhibit; here the unitary operator for the split-step quantum walk, U_{SS}, has chiral symmetry and therefore the Hamiltonian has non-trivial topological structure described in detail in [5].

We create a boundary between different topological phases across the quantum walk lattice and observe localized states near the boundary. This phenomenon is equivalent to zero-energy bound states in the Su-Schrieffer-Heeger model of polyacetylene [6], in which topological properties have long been predicted but never observed.

Topological effects, such as those present in topological insulators and many other fields of physics are currently one of the hottest topics in science and quantum simulation is equally well regarded as an exciting development in physics. This paper combines these two topics elegantly, opening avenues for other proof-of-principle experiments in this area.

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Spin and charge correlations in quantum dots: An exact solution

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The inclusion of charging and spin-exchange interactions within the Universal Hamiltonian description of quantum dots is a highly non-trivial problem owing to the fact that it leads to a formulation of the problem in terms of a non-Abelian action. We present an exact analytical solution of the probem, in particular, in the vicinity of the Stoner instabilty point. We calculate several physical observables, including the tunneling density of states (TDOS) and the spin susceptibility [1]. Due to the presence of spin-exchange interaction, at the vicinity of the instability point the TDOS exhibits a non-monotonous behavior as function of the tunneling energy. This effect survives even at temperatures higher than the exchange energy. Our results for the spin susceptibility and TDOS are exteded to the presence of the Zeeman splitting [2]. Our approach is generalizable to a broad set of observables, including the a.c. susceptibility and the absorption spectrum for anisotropic spin interaction. Experimentally, our results could be tested in nearly ferromagnetic materials. This analysis is a first step towards solving more complicated problems of transport in quantum dots with spin-exchange interaction, addressing such effects as level statistics at low temperatures, superconducting fluctuations, and non-equilibrium conditions.

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P10

Heat conduction in a force-driven lattice

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Thermal transportation in nanoscale systems has attracted a lot of interest in recent years due to the progress in nanotechnology. In this work, we study by nonequilibrium molecular dynamics simulations the heat conduction through a one dimensional nonlinear lattice coupled to Langevin reservories (with time varying heath bath) and in the presence of a periodical driving force. We explore the resonance behavior of the energy transport when the frequency of the thermal bias is shifted in relation to the external driving one. We analyze the thermal properties and the possibility to achieve a heat pumping device in this force-thermal-driven system.

Quantum phase diffusion in superconducting quantum points

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We analyze the influence of quantum fluctuations on phase diffusion in resistively shunted superconducting quantum points subject to a an external ac voltage. From the Smoluchowski equation of the problem, we study numerically these effects on the probability density of the phase difference between the leads. We calculate the current voltage characteristics and we discuss the effect on fractional Shapiro steps comparing with the classical case.

P12

Ion crystals in optical resonators

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We study the dynamics of a chain of ultracold ions, which is confined inside a standing-wave optical resonator, in the regime in which a dipolar transition of the ion couples with a cavity mode and the cavity is pumped. A similar situation has been recently experimentally realised in [1]. In this regime the ions motion is determined by the trapping potential, the Coulomb repulsion, and the quantum potential of the cavity field. We analyze the different regimes that can be attained when the detuning and intensity of the pump field are varied. We first consider the case in which the cavity field represents a negligible perturbation to the dynamics of the ions, and study how to obtain information about the structure and dynamics of the ion chain by measuring the light at the cavity output. We then consider the case when the mean number of cavity photons is large and the electromagnetic field can be treated as classical, and study the mapping of the system dynamics to the well-known Frenkel-Kontorova model [2]. We finally analyze the behaviour of the system when the back-action of the cavity field on the ions dynamics cannot be neglected [3]. For this situation, we study the normal modes of the chain, focusing in particular on the linear-zigzag structural transition [4].

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Time-dependent heat current and thermoelectricity in a nano-junction

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In the last years, there is a renewed interest in thermoelectric effects. One of the reasons is the experimental observation of values much larger than 1 for the figure of merit ZT, which is the quantity that measures the effectiveness of devices based on thermoelectricity. Currently, the maximum value, which is ZT = 2.4, was obtained in p-type Bi_2Te_3/Sb_2Te_3 superlattice devices [1]. It is estimated that one should design a device with ZT $>$ 3 to be competitive with conventional refrigerators or generators [2].

A proposal to move towards this goal is the study of thermoelectric in mesoscopic systems and nano-junctions [3,4]. Since the figure of merit is proportional to the product between the Seebeck coefficient (which measures the heat to voltage conversion) and the Peltier coefficient (which measures the electric to heat conversion), it is important to find the mechanisms which can enhanced these coefficients in such nanoscale systems.

One of these mechanisms is the application of an abrupt time-dependent gate voltage in a metal/dot/metal junction [5]. Another one is the application of a time-modulated gate voltage to the same system. We will present our calculations of time-dependent electric, energy and heat currents in the presence of a time modulation, and we will discuss the definitions of Seebeck and Petlier coefficients, in both linear and non-linear response regimes.

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P14

Electronic properties of an arbitrary quantum ring contour in the presence of a magnetic field

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The influence of an arbitrary contour of a quantum ring (QR) on the ring's electronic properties is studied. Although electronic properties of circular QR are well studied theoretically, distorted QR are typically treated mainly for specific symmetries using numerical methods. The energy states and persistent current (PC) in a non-circular QR were considered in [1] for a ring of constant width and a very special, distorted contour. Specific effects arising from variation of the ring width for arbitrary and elliptical shapes were studied numerically in [2,3].

The energy states and PC oscillations considered here are formulated in a one-dimensional model for a QR with a nearly circular arbitrary contour. Using conformal mapping, the curvature of the ring is introduced into the Schrodinger equation via the Lame coefficient of the conformal mapping. An asymptotic method was employed in order to derive analytic solutions. We show that the energy of the non-circular ring is a periodic function of the flux Φ, and always has certain gaps, depending on the order of symmetry. Energy levels and current oscillations were studied for three cases of possible non-circular QR symmetries.

In the case of a QR with two axes of symmetry (ellipse), our analytical results are in good agreement with those of earlier numerical models that showed that the energy gaps appear at the integer values of the flux. Such gaps broaden as the ellipticity increases and their widths decrease monotonically as the energy levels increases. For the case of a QR with one axis of symmetry we found that, in addition to gaps at the integer flux values, this symmetry opens new, additional energy gaps at the half-integer values of the flux as well. These gaps behave similarly to those in the elliptical rings.

Our approach is implemented also on QRs with no axes of symmetry, i.e. asymmetric shapes. We found that this lack of symmetry opens energy gaps at the half-integer and integer values of the flux, but unlike the previous two symmetries treated, we found that the asymmetry of the QR causes some chaos in the width of the gaps. To the best of our knowledge, this is the first time explicit formulae have been established for non-circular shapes. In particular, for the elliptical contour, when the ellipticity is small and Φ is not too close to the multiply fundamental quantum flux Φ_0, very simple approximate formulae were found for the spectrum and the current. These formulae allowed us to study the angular dependence of the current in the elliptical QR. Explicit expressions for three lowest energy gaps are obtained as well.

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Non-equilibrium quantum criticality in Josephson junctions and 1d quantum gases: A real-time RG approach

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It is well known that equilibrium quantum systems in the vicinity of a continuous phase transition show a universal scaling behavior, known as "quantum criticality". In a recent paper [1], we found specific examples of "non-equilibrium quantum criticality", occurring in quantum systems driven by time-dependent noise with 1/f spectrum. Here, we complement this result by studying small perturbations around the critical point, through an appropriate real-time renormalization group (RG) approach. We find that these perturbations lead to the generation of a finite effective temperature, which eventually destroys the critical state. As the effective temperature is perturbatively small, it is nevertheless possible to observe clear signatures of a continuous non-equilibrium transition at intermediate scales. We exemplify our general approach by computing exact analytic expressions for the RG flow of noise-driven shunted Josephson junctions and interacting particles in one dimension.

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P16

Modifications of the MAF quantization rule for the bound states of 1D symmetrical potential wells

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Modifications due to the phase matching at the classical turning points of two turning point systems for the traditional first order JWKB method given by [1] and [2] has been shown to be also applicable for the Modified Airy Function (MAF) method, which involves the universal MAF constants for the bound states of the symmetrical potential wells where the potential is an even function as given in [3]. Origins and computations of the universal MAF constants including the higher excited states which will have a special importance here are being given and the resulting modified MAF quantization rule which can easily be obtained by a simple modification rule according to the sharpness conditions of the turning points are being presented. Results of the square well applications where both classical turning points are the sharpest, i.e., discontinuous show greatly enhanced eigenenergies as the state number increases where the traditional unmodified semiclassical quantization rule to such systems should inevitably fail due to the sharpness of the potentials. Turning point phase considerations of the fundamental quantum theories resulting in the hereby presented modified MAF quantization rule becomes more complete and seems to be useful for such symmetrical sharp potential wells. It is also shown that the modifications presented here makes the modified and unmodified MAF quantization rule equal to give exact results for the simple V shaped potential well whose slopes are ± 1.

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Mathematical aspect of quantum mechanics by means of semiclassical analysis

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Why sometimes one of the exponential terms in quantum mechanical solutions should cancel is being explained mathematically by means of the semiclassical analysis and the generalization of “S tilde” matrix elements made up of the semiclassical expansion terms as in [1] for the decision on which term to cancel is being presented. It is shown that the fundamental assumption lying in the theory of quantum mechanics, which can be stated by “in a quantum mechanical system, there should be no reflecting wave from infinity (so that a quantum mechanically acceptable, i.e., a normalisable wavefunction can be enabled)” lacking a full mathematical & quantum mechanical insight other than via normalisation, where it can be counted as explicitly quantum mechanical (not explicitly mathematical), is being established explicitly mathematically. So, the quantum mechanical fitting based on the quantum mechanical assumption given above is being shown mathematically by the use of the formal JWKB expansion formula and an establishment of duality of mathematics and quantum mechanics, with the results of the applications are being presented. Finally, the general mathematical formalism for higher order approximations which can be needed in some situations is been presented and the results of the model applications are being discussed.

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P18

Entanglement dynamics of two strongly driven qubits

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We study a system of two driven qubits individually coupled to a single mode cavity subject to Markovian dissipation modelled by Lindblad equation. In the limit of strong driving we see that the system dynamics simplifies and in that regime we find a phenomenon of a periodic partial bipartite entanglement revival. We explain this effect through generation of entanglement between the qubits and the cavity in the framework of monogamy of entanglement in the tripartite qubits-cavity system. Moreover we also show how this system can be used to probabilistically generate qubit-qubit entanglement through a cavity measurement when the system operates in the decoherence-free subspace (DFS). Lastly, outside the DFS the degree of entanglement (measured by concurrence) created can still be very high is the measurement performed is appropriately timed.

Additionally, we present our recent results on driven bimodal parametric oscillator undergoing Markovian dissipation.

Observation of a signaling through wavefunction collapse

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A signaling through wavefunction collapse has been observed under the conditions beyond the no-signaling (Eberhard) theorem. We have implemented an original communication procedure which differs in principle from conventional EPR-like procedures. The proposed procedure is based on the assumption of existence of a quantum system, the eigenstates of which are spatially-separated macroscopic-scale quantum orbits. No such systems have been known so far. In this work, however, we just report on the discovering of a suitable quantum system. It is a macroscopic quantum phase that emerges from the Quantum Hall state of matter through continuous quantum phase transition accompanied by the breaking of translational symmetry and controlled by the system's toroidal moment. In a sense, a system in the phase behaves thus as a gigantic single atom with a great number of spatially-separated electron orbitals covered the entire system with no spatial periodicity. The lengthscale of the orbitals appears thus just the entire system lengthscale. The electrons in these orbitals appear nonlocal so that the lengthscale of their nonlocality is thus easy to control and has no limitations of a fundamental character.

A partial illumination of such a macroscopic "atom" may give rise to macroscopic-scale vacant orbitals which instantaneously become available to transit into for unexcited electrons from neighbouring orbitals. The relaxation transitions may well occur far beyond the laser spot within the length of the vacant orbitals and these transitions are easy to detect. Through a strong enough excitation we can always provide the so high density of vacant orbitals that the detection will be of a nearly hundred-percent probability in a local system's domain beyond the laser spot. In a banner experiment, we reliably detect the relaxation transitions at a distance as long as about 1cm despite the fact that their characteristic time is shorter than 1ps. The nominal speed of signaling is thus nearly two orders faster than the relativistic limit. This experiment, however, by no means challenge the basic relativistic postulate related to the impossibility of a faster-than-light motion at least insofar as the notion of wavefunction collapse is beyond the very paradigm of motion. Rather, it strongly challenges such a seemingly self-evident thing as the inseparability of signaling from a real motion of something and the consequential interpretation of such fundamental notion as simultaneity as well as causality in terms of special relativity.

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P20

Landau quantization for induced dipole in a quantum ring

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In this contribution, we discuss how the Landau quantization for dipole moments can be achieved in the presence of a classical background based on linear topological defects. We consider a nonrelativistic neutral particle having either a permanent magnetic dipole moment or an induced electric dipole moment, and interacting with external electric and magnetic fields in a background made of a disclination and a dislocation. Hence, we show how must be the field configuration which allows the Landau quantization to be achieved and how is the influence of a linear topological defect on the energy levels of the bound states. We also show, in the Landau-Aharonov-Casher system, that bound states can be achieved when the neutral particle is confined to the quantum anti-dot, quantum dot and the two-dimensional quantum ring.

High frequency third cumulant of current noise: Existence of quantum correlations in the zero-point fluctuations of electrons

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We have measured the high frequency third cumulant of voltage quantum fluctuations across a tunnel junction in the high frequency regime $\hbar\omega \gg eV \gg k_B T$. This quantity is obtained by correlating the fluctuations of the high frequency noise power with the low frequency part of the fluctuating voltage. In this regime, the high frequency voltage/current fluctuations are due to zero point motion of electrons. We obtain that the third cumulant of current fluctuations is simply given by $e^2 I$, independent of ω. Despite its classical look, this result expresses that the fluctuations of the square of the high frequency current due to vacuum fluctuations are correlated with the low frequency fluctuating current. We discuss how this result raises the problem of how to calculate high order correlators in quantum mechanics for a given experimental setup.

P22

Resonant states and open quantum systems

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Open quantum systems are usually described as the result of the coupling of a closed system with an environment via perturbation theory. This has a long and distinguished history [1]. There is also the description of a distinguished class of open quantum systems that goes back to the old days of quantum mechanics which arose in connection with the description of the time evolution of decay. This approach involves an exact analytical treatment that in modern times has led to the formulation of the theory of resonant states that is based on the analytical properties of the outgoing Green's function to the problem [2]. Resonant states are defined by imposing outgoing boundary conditions to the solutions to the Schroedinger equation. The above formulation leads to complex energy eigenvalues and hence to a Non-Hermitian quantum mechanical formulation. This contribution discusses some properties of resonant states, specifically, regarding the issues of normalization and eigenfunction expansions and how they may be applied to the description of the time evolution of decay along the full time interval both for the exponential and nonexponential regimes. It is also shown that the analytical description in terms of resonant states yields identical results to a description, essentially numerical, based on the continuum scattering states to the problem.

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P23

Current polarization and multichannel effects in a localizad Rasaba interaction

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We investigate intersubband mixing effects in multichannel quantum wires in the presence of Rashba spin-orbit coupling and attached to two terminals. When the contacts are ferromagnetic and their magnetization direction is perpendicular to the Rashba field, the spin-transistor current is expected to depend in an oscillatory way on the Rashba coupling strength due to spin coherent oscillations of the traveling electrons. Nevertheless, we find that the presence of many propagating modes strongly influences the spin precession effect, leading to (i) a quenching of the oscillations and (ii) strongly irregular curves for high values of the Rashba coupling. We also observe that in the case of leads' magnetization parallel to the Rashba field, the conductance departs from a uniform value as the Rashba strength increases. We also discuss the Rashba interaction-induced current-polarization effects when the contacts are not magnetic and investigate how this mechanism is affected by the presence of several propagating channels.

P24

An engine fueled by unread quantum measurements

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We propose a quantum thermodynamic engine wherein work is performed by a system in contact with a single bath. The engine is fueled by a non-selective quantum non demolition measurement. The seeming contradiction with the second law of thermodynamics is resolved. The model represents an alternative scheme for running an engine, which can increases its efficiency.

Dynamics of entanglement in an oscillating bipartite Gaussian state

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Each particle of an entangled bipartite Gaussian state is coupled to an independent reservoir. A harmonic oscillation is allowed between the two particles. The particles are assumed to be coupled to the reservoirs with different coupling strengths and the reservoirs are assumed to have different temperatures. This allows for a realistic situation where a bipartite state may be shared between two parties and hence ”kept” in different environments. A master equation, previously derived in the non-rotating wave approximation, is solved for the system. The effects of a variation in the bath temperature on the entanglement, as well as that of the variation in coupling strengths and in the initial conditions, are shown.

P26

Striation-generating curves corresponding to the mutually unbiased bases

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The mutually unbiased bases are the cornerstone of the modern quantum information. Suppose that we have an unknown quantum state and our task is to extract as much information as possible. When the dimension of the Hilbert space is finite, it was proved that the optimal tomography is obtained if a special class of states is used: mutually unbiased bases (MUBs) [1].

MUBs can be constructed using different methods. Wootters [2] and Gibbons et all. [3] proposed a method to associate the MUBs to the so-called discrete phase space. The phase space of a d-level system (qudit) is a d X d lattice, whose coordinates are elements of the finite Galois field GF(d). Further a state is associated to a line in the discrete phase space. The set of parallel lines is called a striation [2]. It was proved in the case when d is a power of a prime number that one has to generate families of unitary operators, whose eigenvectors solve the problem of MUBs [4]. In other words, instead of searching for the set of MUBs, one needs to determine d + 1 classes of d – 1 commuting operators. Some particular mutually unbiased operators were found for two or three qubits [5]. Bjork et all. proposed to select each ray of all striations and construct a table with them [6]. Accordingly, if one obtains the table of rays, then easily one can generate the MUBs.

We propose a new method of finding the MUBs for multi-qubit systems. The key element is the construction of the table of striation-generating curves in the discrete phase space. We derive a set of equations in the Galois field and show that the solutions of these equations are sufficient for the construction of MUBs.

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Quantum kinetic theory of superfluid internal convection

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When a superfluid is heated locally, one observes a superfluid current from colder to hotter regions, while the thermal fraction flows in the opposite direction. This "internal convection" is usually described within Landau's phenomenological two fluid model, but we obtain a more fundamental picture by extending a standard master equation formulation of quantum kinetic theory to include two reservoirs of different temperatures. We find that internal convection arises even in collisionless regimes, and predict that it can be observed in trapped ultracold Bose gases.

P28

Proposal for an optical laser producing light at half the Josephson frequency

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We study the emission of visible laser light by a superconducting device at half the Josephson generation frequency. The device consists of a single mode optical cavity containing a p-n semiconductor nanowire that is attached to superconducting leads. Two quantum dots are embedded in the nanowire via which emission of photons by electron-hole recombination can occur. The cavity induces a phase locking between optical phase and superconducting phase difference. Spontaneous switchings within the device are studied as a source of decoherence. These switchings guarantee stationary lasing states for suitable parameter regimes.

Orthogonality catastrophe via qubit embedding in an ultra-cold Fermi gas

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We investigate the behaviour of a single qubit coupled to a low-dimensional, ultra-cold Fermi gas. The scattering between the system and the fermions leads to the loss of any coherence in the initial state of the qubit and we show that the exact dynamics of this process is strongly influenced by the effect of the orthogonality catastrophe within the gas. We highlight the relationship between the Loschmidt echo and the retarded Green's function - typically used to formulate the dynamical theory of the catastrophe - and demonstrate that the effect can be triggered and characterized via local operations on the qubit. We demonstrate how the expected broadening of the spectral function can be observed using Ramsey interferometry on the qubit.

P30

Effect of interactions on thermal properties of Fermi gas confined in a harmonic potential

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In this work, effect of Coulomb interactions on thermal properties like total energy, pressure, free energy of an Fermi system are investigated numerically. For this purpose, Thomas-Fermi equation [1] is solved for harmonically confined interacting Fermi system at finite temperature. Numerical results are compared with analytical ones given in literature for noninteracting case [2] at finite temperature and for interacting case at T = 0 K [3] and excellent agreement is achieved. Results indicate that interactions affect density distribution and hence density dependent thermal functions significantly.

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Quantifying, characterizing and controlling information flow in ultracold atomic gases

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We present here the first characterization of non-Markovian effects in the context of ultracold gases [1]. More specifically, inspired by a model introduced in Ref. [2] we consider the process of an impurity atom in a double well potential, an effective qubit system, interacting with an ultracold Bose-Einstein condensed (BEC) environment. We study quantum information flow between the qubit system and the BEC environment using quantifier presented in Ref. [3].

We show how information flux can be manipulated by experimentally achievable means such as changing the scattering length of the condensate and of the qubit-boson collisions and by modifying the potentials that confine the BEC and the qubit. Under specific conditions we find the existence of a crossover in the parameter space of the model between Markovian dynamcs, characterized by information leaking from the qubit to the environment, and non-Markovian dynamics, characterized by a temporary reversal of information flux.

Moreover, we unveil an intimate link between the spectral density of the reservoir and non-Markovian effects in the qubit dynamics. Our findings pave the way to the realization of quantum simulators for non-Markovian open quantum system models with ultracold atomic gases.

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P32

Theory of quantum mechanics incorporating nonlocality and measurements in a natural way

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We propose a new theory of quantum mechanics that avoids several deficiencies of the generally accepted theory. The new theory is nonlinear and nonlocal, thus removing the need for a supplementary "collapse" process. With a single law that applies universally, it is no longer necessary to define certain events as "measurements" so as to distinguish the regimes of validity of the wave equation and the collapse process. Thus we avoid the "measurement problem."

The new quantum mechanical law proposed here is expressed in a relativistically covariant way as a variational principle. In the functional to be minimized, expressions quadratic and quartic in the wavefunction are integrated over space and time, thus providing the required nonlinearity and nonlocality. The evolution of the wavefunction (including the outcome of any experiment) is determined in part by a "hidden variable" (the phase of the wavefunction as manifested in zitterbewegung, or equivalently the start time of the experiment relative to the zitterbewegung).

A theoretical confirmation of the gravitation new origin, having a special electrical nature

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In this paper one starts by analyzing the actual justification of the separation existing between electrical and gravitational forces. It is that for neutral bodies the electrical dipole interaction force at long distances r, totaly cancels as equal and opposed forces given by Coulomb's law. Moreover, was demonstrated in the paper, that the type of the force between two dipoles with the same orientation - attraction or repulsion - is given by the variation mode of the force with the r distance, being always attraction for decreasing force with distance, and always attraction in the contrary case. This electrical dipole force may exist at any distance, but it depends on a term in $1/r^4$ or greater, being negligible compared to the gravitational force. As well in order to obtain the principal term in $1/r^2$, also for electrical dipole interaction, it was necessary and sufficiently to admit a hypothesis which considers the Coulomb law, a series of terms of powers of r, including a new term of the form -ln r. With the corrected Coulomb law for dipole interaction force, an expression having the principal term in $1/r^2$ results as in the gravitation force law. In order to verify the above hypothesis, numerical chekings was made utilizing actual electric permeability. These calculations made for a planetary distance, showed a good agreement (relative ratio R = 2.5) between the Newton's force and corrected Coulomb's force. The best agreement is obtained when the polarization of all nucleons including the neutrons is considered (R = 0.62). On the basis of this gravity theory, some important consequences and conclusions result [1]. The electromagnetic interactions based on the corrected Coulomb's law are the only necessary and sufficiently to yield all of the known forces in nature, so unifying them. The actual Newton's law looses its object toghether with the attempts and experiments aiming to detect the gravitational waves. The simultaneous and multi-direction intercations between dipoles, supposed by our theory, are physically possible only in quantum manifestation of the charges, and admitting the presence of a continuum media (as a modern ether), as absolute support of electromagnetic interactions. As a consequence, this continuum media must yield the inutility of special rlativity theory principles, as is argued by our new interpretation of Michelson experiment which contradicts the classical interpretation. In the general reltivity theory, the so called space/time entity and his gravitational curvature will lose their starting basis, the actual gravitational force. In astrophysics the so called black holes, loose their theoretical basis. In cosmology the so called big-bang event, loose its theoretical basis.

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P34

Time propagation of the Nonequilibrium Green's function for strongly correlated electrons using the generalized Kadanoff-Baym ansatz

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For the description of many-particle systems the Nonequilibrium Green's function method has become widely used in the last decades. The equations of motion for this quantity are the Keldysh-Kadanoff-Baym equations (KKBE). The simplest approximation that includes correlation effects is the second Born approximation. However, as the two-time structure leads to quadratic scaling of the memory cost with simulation length, only short term dynamics can be computed.

By introducing the generalized Kadanoff-Baym ansatz (GKBA) ansatz into the KKBE, the two-particle Green's function is reconstructed from its value on the time diagonal [1]. This leads to a linear scaling of the memory cost with simulation length which makes longer time evolution possible.

In this contribution, we apply the GKBA to the time evolution of a 4-electron quantum dot as a model for inhomogenous systems. With results for time dependent spatial and spectral properties the GKBA is compared to two-time 2nd Born-, Hartree-Fock-calculations [2,3] as well as to the exact solution of the time-dependent Schrödinger equation. A special focus thereby lies on how well 2-electron excitations, which play an important role for the correlated electron dynamics, are represented in GKBA calculations.

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Concurrence in disordered systems

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Quantum systems exist at finite temperatures and are likely to be disordered to some level. Since applications of quantum information often rely on entanglement, we require methods which allow entanglement measures to be calculated in the presence of disorder at non-zero temperatures. We demonstrate how the disorder averaged concurrence can be calculated using thermal many-body perturbation theory. Our technique can also be applied to other entanglement measures. To illustrate, we find the disorder averaged concurrence of an XY spin chain.

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An extension of the exchange fluctuation theorem for initially correlated systems

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In [1], it is shown that the probability distributions of the exchanged energy between two systems satisfy a relation independent of the interaction between them, if the initial state is given by a tensor product of the canonical states of systems with generally different temperatures. This relationship holds for both quantum and classical systems and is called the exchange fluctuation theorem, which is a consequence of the time reversal symmetry. The theorem can be understood as the existence of a universal relationship for the probability distributions of the change of local observables, namely, the change of the average local energy in [1], for interacting systems under these conditions. In this poster, we analyze an extension of the exchange fluctuation theorem for initially correlated systems to investigate the existence of such universal properties for more general observables and initial states.

We derive a relationship between the probability distributions that simulate the change of expectation values of observables under any kind of unitary operations for initially correlated systems, under certain conditions on the initial state. When the reduced density matrices are given by the canonical states, and the unitary operation is the time evolution by a Hamiltonian which preserves the total energy, the resulting relationship provides the exchange fluctuation theorem modified by the effect of correlation described by a quantity similar to the difference in the mutual information of the initial and final states. From the modified theorem, an inequality for the exchanged energy is obtained, which can be interpreted as showing that energy can flow from the lower temperature system to the higher one as a result of the existence of initial correlations.

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Emergence of non-thermal statistics in isolated quantum spin clusters

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The statistical properties of isolated interacting many-body systems have recently received considerable attention in both experimental and theoretical aspects. Interests on such systems are primarily inspired by the possible implementations of them on the spin clusters, quantum dots, q-bit systems, optical lattices and cold atomic gases. These artificial systems with tunable interactions facilitate an exploration on the fundamental issues of quantum statistics, for example the nonequilibrium dynamics of a closed quantum system.

In this work, we discuss the emergence of a non-thermal statistics in the isolated quantum spin clusters. By performing computer simulations, we show that, if a finite isolated cluster of interacting spins 1/2 is subjected to a series of small non-adiabatic perturbations by the external magnetic field, then the resulting occupation distributions are no longer of the conventional Boltzmann-Gibbs statistics, even though the staring distributions are of the thermal type. The emerging non-thermal occupations are significantly higher than the thermal ones on both the low and the high ends of the energy spectra. This behavior semi-quantitatively agrees with the statistics predicted for the "quantum micro-canonical" (QMC) ensemble [1,2]. The QMC ensemble admits all possible superpositions of energy eigenstates with a specified energy expectation value. The fact that all energy eigenstates can participate in the QMC ensemble distinguishes it from the conventional microcanonical ensemble, where participation of energy eigenstatates is only limited to a narrow energy window around the energy expectation value.

In our study, we have found that the process of transition towards the QMC-like statistics crucially depends on driving pulses. We present the results for two different pulse sequences which produce very different convergence rates. Our results also indicate that the eigenstates of the perturbation operators are generally localized in the energy basis of the unperturbed Hamiltonian if the perturbations are periodically applied. This kind of localization can protect the thermal behavior in the macroscopic limit against the QMC-like statistics, but can also be significantly suppressed by slightly randomizing the pulse delays.

Finally, we propose that one can obtain the experimental evidence of the QMC-like statistics by performing adiabatic magnetization of the spin clusters.

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Entanglement dynamics: Evolution equation and bipartite invariants

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The estimation of entanglement of multipartite systems undergoing decoherence is important for assesseing the robustness of quantum information processes. It usually requires access to the final state and its full reconstruction throgh quantum tomography. General dynamical laws may simplify this task. We found that when one of the parties of an initially entangled two qubit system is subject to a noisy channel, a single universal curve describes the dynamics of entanglement for both pure and mixed states [1,2], including those for which entanglement suddenly disappears [3]. Our result, which is experimentally demonstrated using a linear optics setup, leads to a direct and efficient determination of entanglement through the knowledge of the initial state and single-party process tomography alone, foregoing the need to reconstruct the final state.

In addition, we show that in a similar scenarium and for the specific case of the amplitude damping channel, there exist a conservation law that relates the quantities characterizing the bipartite entanglement between each of the parties and the other two [4]. We provide an experimental demonstration of this using entangled photons and generalize it to N-partite GHZ states.

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Bayesian approach and maximum work characteristics of heat engines

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In this presentation, we propose that various thermal efficiencies, such as Curzon-Ahlborn (CA) efficiency and others close to it, which are observed in so many models of heat engines, have an informational basis rooted in Bayesian probabilities [1]. These probabilities represent state of our knowledge about the system and are in this sense subjective in nature. We employ a Bayesian perspective to first analyze the performance of an infinitely slow Otto cycle for a quantum engine operating between a hot (T_1) and a cold (T_2) reservoir. The total work in a cycle can be expressed as $\mathcal{W}(a_1, \eta)$, where η is the cycle efficiency and a_1 is an external control parameter appearing in the hamiltonian. For simplicity, we consider a two-level system with energy levels 0 and a_1. Imagine that η is specified to us, but a_1 is unknown. Within the Bayesian approach, the expected work per cycle is defined as [2]

$$\overline{W}(\eta) = \int_{a_{\min}}^{a_{\max}} \mathcal{W}(a_1, \eta)\Pi(a_1)da_1, \tag{1}$$

where $\Pi(a_1)$ is the prior probability distribution. The choice of appropriate prior is crucial in Bayesian statistics. We show that for Jeffreys' prior $\Pi(a_1) \propto 1/a_1$, the expected work becomes *maximal* at CA value, given by $1 - \sqrt{T_2/T_1}$. We also investigate a general class of priors $\Pi(a_1) \propto 1/(a_1)^\gamma$. The uniform prior as proposed by Laplace and Bayes can also be accomodated in this framework. For close to equilibrium ($T_1 \approx T_2$), the efficiency at optimal work for such priors behaves like $\eta^* \approx \eta_c/2$. where $\eta_c = 1 - T_2/T_1$. Thus the choice of power-law prior $\Pi(a_1) \propto 1/(a_1)^\gamma$ leads to efficiencies close to CA value and which resemble the results obtained with finite-time cycles [3] and finite heat source/sink models [4]. We also discuss Bayesian approach to estimate efficiency of classical Otto cycle and point out that with power-law form of prior, the expected work becomes maximum with Jeffreys choice. These findings suggest there a deeper connection between Bayesian probabilities and thermodynamic behavior.

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Entangling two distant oscillators with a quantum reservoir

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The generation of entanglement between two oscillators that interact via a common reservoir is theoretically studied. The reservoir is modeled by a one-dimensional harmonic crystal initially in thermal equilibrium. Starting from a separable state, the oscillators can become entangled after a transient time, that is of the order of the thermalization time scale. This behavior is observed at finite temperature even when the oscillators are at a distance significantly larger than the crystal's interparticle spacing. The underlying physical mechanisms can be explained by the dynamical properties of the collective variables of the two oscillators which may decouple from or be squeezed by the reservoir.

Electron transport in a mesoscopic ring: Effects of Rashba and Dresselhaus spin-orbit interactions

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In this communication we present an in-depth study of the phenomenon of persistent current in a mesoscopic ring in the presence of both the Rashba spin-orbit interaction (RSOI) and the Dresselhaus spin-orbit interaction (DSOI) within the tight-binding framework. Quantum rings formed at the interface of two semiconducting materials are ideal candidates where the interplay of the RSOI and the DSOI might be observed. The motivation behind the present work is twofold. First, we wish to look for a possible method of determining the strength of DSOI in a simply connected mesoscopic ring. In recent past there have been a few experimental attempts [1] to measure the strength of DSOI, but a theoretical proposal regarding how to measure the strength of DSOI is still lacking. Second, there is a long standing anomaly between the observed large persistent current in a disordered mesoscopic ring, and the corresponding theoretical prediction. Experimental observations suggest a current, an order of magnitude larger than the theoretical estimates.

In this work we address these issues. While looking for a way to estimate the strength of the DSOI, we present a analytical method to calculate the energy dispersion of the mesoscopic ring either with RSOI or with the DSOI, thus gaining a clear insight into the band structure. This finally leads to the fact that by making the strengths of the RSOI and the DSOI equal, one comes across an absolute minimum in the conductance of the ring. As the RSOI can be tuned and estimated by controlling an external gate voltage, the estimation of the DSOI becomes obvious. The conductance is calculated via the Drude weight numerically, and is found to support our analytical understanding. In the second part, we show that the enhancement of persistent current in a disordered ring may be attributed to the presence of the SOI. It is observed even with the RSOI alone. This might resolve the anomaly between earlier theories and experiments. In addition to these, we present the detailed energy band structures, the oscillations of persistent current as the RSOI is varied, as well as the dependence of current on the number of electrons in the system to get a complete picture about the phenomenon.

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Nanogaps for nanomechanical displacement sensing

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There has recently been a great effort to fabricate nanogaps, two metallic electrodes with a few-nanometer or a sub-nanometer gap, to study the electronic properties of nanoscale structures like single molecules and nanocrystals. A nanogap in the tunneling regime can in principle be utilized as a sensitive displacement sensor with nearly quantum limited sensitivity [1,2]. Although various nanogap fabrication techniques have been already been developed they either suffer from low yield, uncontrolled or bulky [3,4]. Here we report a new fabrication technique based on the controlled-shrinkage of a wide gap down to a vacuum tunneling gap with predetermined conductance.

The devices were fabricated on a Si wafer with a SiO_2 and a Si_3N_4 layers on top it. The metallic tips were defined using electron-beam lithography. Then the metallic tips were exposed to thermally evaporated Au atoms and the gap size between the electrodes is reduced while the conductance between the gaps was continuously monitored. Evaporation is halted as soon as the desired conductance is achieved. The sizes of the gaps are typically smaller than few nanometers. After the tunneling gap was fabricated, its current-voltage characteristics were measured. The fitting of the experimental data to the well-known Simmons model to determine and the gap size.

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A measurement method for the squeezing parameter of the number states photon in a quantum cavity

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An interesting setup for the experimental measurement of zero or one photon in a quantum cavity has introduced by Lutterbach [1] and Nogues [2]. For this purpose, the Wigner distribution function measurement in the origin of coordinate system has performed. In our paper we are going to show the development of this method for more than one photon, with the measurement of displaced Wigner distribution function. Then this method could be applied for the measurement of the squeezing parameter of the number state in a quantum cavity.

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A non-classicallity indicator for the squeezing and entanglment

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Recently, new non-classicality indicator introduced by Sadeghi et. al [1]. There are more benefits with respect to the negativity indicators. Clearly the negativity indicators can't show the squeezing properties, which has no effects on the Wigner distribution function negativity. In this paper we show the new non-classicality indicator illustrate the squeezing effects as well as entanglement of a two level quantum system. This method has developed for the Husimi and Rivier distribution functions.

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Two-mode nonclassical correlations of light generated by a beam splitter

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The density operator of a multi-mode radiation field $\hat{\rho}$ can be in general expressed in terms of coherent states as

$$\hat{\rho} = \int \cdots \int P(\{v\}) |\{v\}\rangle\langle\{v\}| \prod_i d^2 v_i. \tag{2}$$

where $P(\{v\})$ is a function of multi-complex variables $\{v\}$. P-function plays the role of a probability distribution in the classical probability theory. For a nonclassical state of light, however, the corresponding P-function is often negative over some point in the domain of variables or more singular than a delta function. This undesired behavior of P-function can be eliminated by some regularization process. If we define R-function as

$$R_\tau(\{v\}) = \int \cdots \int \prod_i \left(\frac{1}{\pi\tau} e^{-|v_i - v_i'|^2/\tau} \right) P(\{v'\}) \prod_i d^2 v_i, \tag{3}$$

then R-function becomes a true probability distribution above a certain value of τ, which we denote by τ_m, and we take τ_m as the nonclassical measure of a nonclassical light. This multi-mode nonclassical measure was applied to a beam splitter and it was shown that the two mode nonclassical measure is preserved on passing through a beam splitter.

In this paper, we explore the implication of invariance of two-mode nonclassical measures on passing through a beam splitter. On denoting two input modes by a and b, and two output modes by c and d, we have two two-mode nonclassical measures $\tau_m^{(ab)}$ and $\tau_m^{(cd)}$, and four single mode nonclassical measures $\tau_m^{(a)}$, $\tau_m^{(b)}$, $\tau_m^{(c)}$, and $\tau_m^{(d)}$. To obtain single mode nonclassical measures, we need to take partial traces on two-mode density operators over the other mode. These partial traces may reduce nonclassicality of input or output beams, and hence the single mode nonclassical measures cannot be greater than the corresponding two-mode nonclassical measures. When two input beams are statistically independent, the two-mode nonclassical measure of input beams will be determined by the bigger of $\tau_m^{(a)}$ and $\tau_m^{(b)}$. We may assume $\tau_m^{(a)} \geq \tau_m^{(b)}$. $\tau_m^{(a)} = 0$ implies $\tau_m^{(cd)} = 0$ and then $\tau_m^{(c)} = \tau_m^{(d)} = 0$. Therefore, one cannot obtain a nonclassical output from a classical input with a beam splitter. A nonclassical input is necessary to have nonclassical correlations in the output, however, it is not a sufficient condition. When $\tau_m^{(a)}$ is positive, then $\tau_m^{(c)} \leq \tau_m^{(a)}$ and $\tau_m^{(d)} \leq \tau_m^{(a)}$. In particular, when strict inequalities hold, some two-mode nonclassical correlation has been erased in the process of partial traces over the unwanted mode. In other words, the global transformation performed by the beam splitter brings about two-mode nonclassical correlations, including possibly entanglement. We discuss two-mode nonclassical correlations generated by a beam splitter other than entanglement.

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Work fluctuations of a nanomechanical resonator coupled to a single electron transistor

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We study the fluctuations in the work done by an external force applied to a nanomechanical resonator coupled to a single-electron transistor (SET). The SET consists of a small island connected to two leads by tunnel junctions; a gate capacitively coupled to the island can be used to adjust the operating point. We work in a regime where only two charge states are available to the SET, either N or $N + 1$ excess electrons on the island. The SET-resonator system has interesting coupled dynamics; the electron tunnelling rates on to and off of the island depend on the position of the resonator, whilst the fluctuating island charge acts as a stochastic force on the resonator. Previous work has shown that for weak electro-mechanical coupling the SET charges act like an effective thermal bath leading to damping of the resonator and a steady-state probability distribution which is, to a good approximation, Gaussian [1]. We examine the system in the presence of an external drive, and find that the distribution of the work done is almost exactly Gaussian in the limit of very weak electro-mechanical coupling. As the coupling strength is increased the resonator begins to change the noise properties of the SET and non-Gaussian features in the work distribution become more pronounced.

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Constrained dynamics with relaxation due to a structured nano system

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Recent experimental progress has revealed a variety of curious and intriguing near-field optical phenomena at the nanoscale [1]. Such phenomena are now going to be applied to unique nanofabrication and nanophotonic devices leading to a novel functional system, where theoretical studies are expected to play a fundamental role [2]. In this paper, we present an example of such intriguing near-field optical phenomena, and discuss a comprehensive picture to understand and formulate them, where dressing nature of photons is emphasized in the elementary process for a nanoscopic finite system interacting with not “free photons” but “localized photons”, as well as phonons. For example, we intend to simulate photosynthetic phenomena to provide new features or new functions for a nanophotonic device, using semiconductor nanostructure such as quantum dots or disks (QDs). Excitation transfer and collective phenomena [2] due to relaxation and dissipation processes in photon-matter coherence created by laser-QDs interaction at the nanoscale manifests itself with competitions between spatial interaction and temporal relaxation. In such a situation, it is very important to examine the role of structured nano-reference system which is essential to discuss the constrained dynamics with relaxation.

As a typical example, we consider a system which consists of a single quantum dot or disk (QD) with a dipole-allowed state coupled to an input laser field, electronically separated but near-field optically coupled identical QDs with dipole-forbidden states, and a QD with a dipole-allowed state coupled to output radiation field. A perfect excitation transfer may be ideally expected in the system, as well as a perfect spin polarization transfer. However, the ratio of near-field optical coupling to spontaneous emission of free photons as well as phonons degrades photon and matter coherence and spin polarization. Here we have to consider a structured nano-reference system interacting with a relevant system, not a conventional bath system. We discuss the criteria for hierarchical structure of such a reference system, transfer path, excitation transfer efficiency, spin polarization ratio, and so on, to formulate the constrained dynamics. It might open a possibility of controlling the relaxation processes, creation of reaction fields associated with collective phenomena, and manifestation of a new functionality/system [3].

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Phonon affected steady-state transport through molecular quantum dots

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We consider a quantum dot, affected by a local vibrational mode and contacted to macroscopic leads, in the non-equilibrium steady-state regime. We apply a generalized variational Lang-Firsov transformation and solve the equations of motion of the Green functions in the Kadanoff-Baym formalism up to second order in the interaction coefficients. Determining the variational polaron formation parameter by minimizing the grand canonical potential we are able to calculate the electron/polaron spectral function and conductance for the whole parameter regime, i.e. for adiabatic to anti-adiabatic phonon frequencies and weak to strong electron-phonon couplings. We investigate the qualitative impact of the quasiparticle renormalization on the inelastic electron tunneling spectroscopy signatures and discuss the possibility of a polaron induced negative differential conductance. In the ungated high-voltage regime we find that the polaron level follows the lead chemical potential to enhance resonant transport.

Dissipation in nanomechanical systems induced by single-electron transport

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We investigated dissipation in a single-electron tunnelling device coupled to an ac-driven underdamped harmonic nanomechanical oscillator. We found that the stochastic force acting on the nanomechanichal oscillator is the main source of dissipation when single electron tunnelling is the dominant transport mechanism. This stochastic force is of electrostatic origin and becomes larger as the number of charges on the quantum dot increases. In the low bias voltage regime the stochastic force acting out-of-phase with the motion of the oscillator causes a decrease of the effective quality factor in the SET regime as compared to the Coulomb blockade region. For high bias voltages the stochastic force acting in-phase with the motion compensates the out-of-phase force, predicting an increase of the quality factor with bias voltage. This effect was observed experimentally in a carbon nanotube-based NEMS. We have found very good quantitative agreement between the experimental data and the theoretical prediction.

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Witness for initial system-environment correlations in open system dynamics

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We study the evolution of a general open quantum system when the system and its environment are initially correlated. We show that the trace distance between two states of the open system can increase above its initial value, and derive tight upper bounds for the growth of the distinguishability of open system states. This represents a generalization of the contraction property of quantum dynamical maps. The obtained inequalities can be interpreted in terms of the exchange of information between the system and the environment, and lead to a witness for system-environment correlations which can be determined through measurements on the open system alone. We introduce a measurement scheme to detect initial correlations, which neither requires a knowledge of the structure of the environment or of the system-environment interaction, nor a full knowledge of the initial system-environment state.

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Quantum key distribution with qudits via cross-Kerr interaction

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In Ref. [1], a coherent state with sufficiently large amplitude can be represented as balanced superposition of d pseudo-number states,

$$|\alpha\rangle = \exp(-\frac{|\alpha|^2}{2})\sum_{n=0}^{\infty}\frac{\alpha^n}{\sqrt{n!}}|n\rangle = \frac{1}{\sqrt{d}}\sum_{k=0}^{d-1}|\underline{k}\rangle, \tag{4}$$

where orthonormalized basis kets $|\underline{k}\rangle = \sqrt{d}e^{-\frac{|\alpha|^2}{2}}\sum_{m=0}^{\infty}\frac{\alpha^{k+md}|k+md\rangle}{\sqrt{(k+md)!}}$ are pseudo-number states. Each pseudo-number state is group of photon number states with same numbers in modulo d. We also proposed another computational basis, which is called pseudo-phase states and generalized Hadamard transformation of pseudo-number states,

$$|\tilde{l}\rangle = \hat{H}|\underline{l}\rangle = \frac{1}{\sqrt{d}}\sum_{k=0}^{d-1}\omega^{lk}|\underline{k}\rangle = |\omega^l\alpha\rangle, \tag{5}$$

where l is an integer from 0 to $d-1$ and $\omega = e^{\frac{2\pi i}{d}}$. After Kerr interaction with two coherent input states, we can get maximally entangled state of pseudo-number and psedo-phase states in d dimensional Hilbert space, following as

$$e^{\frac{2\pi i}{d}\hat{n}_1\hat{n}_2}|\alpha\rangle_1|\alpha\rangle_2 = \frac{1}{\sqrt{d}}\sum_{k=0}^{d-1}|\underline{k}\rangle_1|\widetilde{k}\rangle_2 = \frac{1}{\sqrt{d}}\sum_{k=0}^{d-1}|\widetilde{k}\rangle_1|\underline{k}\rangle_2. \tag{6}$$

Two legitimate members, Alice and Bob, choose one of two nonorthogonal bases randomly. This is an extending version of BB84 scheme. The only difference is to consider events only; two users choose different computational basis. If they choose different basis and there is no eavesdropper, they should have same numbers.

To demonstrate conditional security of the scheme, we just consider the most simple eavesdropping case, a beamsplitter attack of a eavesdropper. An eavesdropper, Eve, put a beamsplitter with a low reflectivity (R) on the road between Alice and Bob. We analysis conditional security of our scheme by calculating two mutual information, $I_{A:B}$ and $I_{A:E}$ according to several variables such as dimension and reflectance of a beamsplitter through numerical simulation.

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Decoherence, entanglement decay and equilibration produced by chaotic environments

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We investigate decoherence in quantum systems coupled via dephasing-type interactions to an arbitrary environment with chaotic underlying classical dynamics. The coherences of the reduced state of the central system written in the preferential energy eigenbasis are quantum Loschmidt echoes, which in the strong coupling regime are characterized at long times scales by fluctuations around a constant mean value. We show that due to the chaotic dynamics of the environment, the mean value and the width of the Loschmidt echo fluctuations are inversely proportional to the quantity we define as the effective Hilbert space dimension of the environment, which in general is smaller than the dimension of the entire available Hilbert space. Nevertheless, in the semiclassical regime this effective Hilbert space dimension is in general large, in which case even a chaotic environment with few degrees of freedom produces decoherence without revivals. Moreover we show that in this regime the environment always leads the central system to equilibrate to the time average of its reduced density matrix, which corresponds to a diagonal state in the preferential energy eigenbasis. For the case of two uncoupled, initially entangled central systems that interact with identical local quantum environments with chaotic underlying classical dynamics, we show that in the semiclassical limit the equilibration state is not diagonal but is arbitrarily close to a separable state. We confirm our results with numerical simulations in which the environment is modeled by the Quantum Kicked Rotor in the chaotic regime.

Spectral noise of composite edge states in the fractional quantum Hall effect

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Spectral noise is a useful tool to study edge excitations in the fractional Quantum Hall (FQH) regime. We will compute the finite frequency current noise in the weak backscattering limit for tunneling of FQH composite states belonging to the Jain sequence. We will show that the noise peaks pattern gives important informations on the presence of different charge carriers in the system. We will also investigate the modifications induced by interactions with external environments (phonon bath, external circuits) to the expected results at zero and finite temperature.

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Sources of stochasticity in gene expression

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Gene expression is inherently noisy which in turn causes fluctuations in the protein number. Fluctuations also arise during cell division when the existing protein content is divided stochastically among the daughter cells. Here we study different models of stochasticity, involved during the cell division. We consider simple birth-death process like models which have different sources of stochasticity and compare them on the basis of noise they produce. First part of the study involves models with only protein synthesis and the second part involves models with messenger RNA plus protein synthesis. These models are mainly studied numerically but in few cases analytical results are also obtained.

Fermi level of carriers in micro-hulled structure based on heat-resistant metals

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Micro-hulled structure based on metals are widely used in modern nanotechnology, especially when creating high temperature sensors and structural elements based on metal foams. The development of contactless and non-destructive methods for diagnosis and test control parameters of multiply connected matrix base material is a very important and interesting aspect of application [1]. In a heat-resistant metal with volume filling defects (VFD) (micro- and nano-pores with complex topologies and sizes) it is primarily its strength and electrical characteristics. Almost all rapid methods of such measurements are based on both electrical measurements data and on fundamental functional relationships of the microstructure parameters and the dispersion medium carriers. The influence of a material VFD disordered set is the unresolved problem on the electronic properties of the micro heterogeneous heat-resistant materials theory. The new statistical “plasma” approach is proposed in this work. This method is based on the modelling statistical concept of the heterogeneous plasma system (HPS) characteristics. The main point of this approach is the concept of an electrically neutral cell. This cell is the smallest area of the electrically inhomogeneous material released by a multiply connected surface Π extreme of instant self-consistent system electric potential [2]. Statistical equilibrium of the VFD electronic component in the high-temperature metal determines the level of the electrochemical potential F. Moreover according to the principle of free energy minimum, F takes the smallest value. Equilibrium distribution of the local density of the electronic component in the matrix base material and VFD satisfies this condition and is determined by solving the effective electrostatic problem in averaged cell [2]. The external electric field Φ_0 influence on the electrons density distribution in the sample with VFD was determined in the computer experiment. The possibility of creating based on heat-resistant metal with nano-VFD high-temperature sensors was discussed in details.

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P56

Spin: The face of an instant

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Our usual concept of geometry is referred to the shape of matter in space. The shape of an object is an intuitive concept that just requires a look at the object in order to be defined. We have no problem in identifying a sphere, a plane, a pyramid, etc. by simply observing its spatial dimensions. But after Einstein we know that space and time are equivalent, and therefore, it is expectable, a priori, that matter may also exhibit a "shape" in time.

In this paper I propose an interpretation of the quantum property called "spin", as the geometric structure of matter in time. I will reach this conclusion after observing that the entanglement that affects electronic pairs, can be compared with a kind of entanglement that occurs in our daily life, to which, however, we don't pay much attention. This common entanglement is a simple flipping coin. We will see here that the entanglement in a coin occurs in space (I will call it "S-entanglement"). All we have to do is to relax our concept of geometry in the spatial dimensions, and extend it to the fourth dimension of our physical world: time. I will call this new kind "T-entanglement", in order to differentiate it from the previous one, being the latter its regular meaning when we talk about "quantum entanglement".

As it is well known, quantum entanglement is a kind of interaction between elementary particles, which provokes a strange correlation or synchronization affecting some of their properties. The spatial structure is easy to grasp, but the temporal "structure" is not. The comparison of entangled electrons with the regular double-faced coin may help us understand this quantum property and the consequences that it reveals for both elementary particles and the dimension of time, in which the spin property is manifested.

It is a matter of question whether the quantum entanglement is real, or just a defect of our detectors, for the deep consequences of non locality it brings for our concept of the world. With this interpretation, the perfect symmetry between space and time is revealed, and from it, the deep conclusion about the necessity of the a-local essence of the world arises naturally.

Entanglement of impurities in an ultracold environment

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In quantum physics, we often study systems in isolation to avoid disturbances due to environmental effects. However, in recent years the area of open quantum systems has sought to consider a system of interest together with an environment, such as a light field. This area has two key advantages. The experimental challenge of fully isolating systems from outside influences makes an approach that allows us to include an additional environment appealing. Further, with a careful choice of environment, it is possible to have beneficial effects on the subsystem, such as increased stability or sudden death and sudden rebirth of entanglement.

In this research we consider an experimentally realisable system consisting of an optical lattice with two atom impurities superimposed on a dilute Bose-Einstein condensate dephasing environment. The atoms are trapped in a deep double well geometry such that tunneling between adjacent wells is suppressed. There is, however, interaction between the trapped atoms and the Bose-Einstein condensate environment mediated by the Bogoliubov excitations of the condensate.

Using a master equation approach, we calculate the decoherence exponents for the time evolution of the density matrix for the system. We consider two body quantum effects such as quantum correlations and entanglement. Using experimentally accessible parameters of the reservoir and the optical lattice, we create a phase diagram showing the occurrence of quantum effects such as sudden death and rebirth of entanglement for different parameter regimes.

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Hartman effect and spin precession in graphene

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Spin precession has been used to measure the transmission time τ over a distance L in a graphene sheet. Since conduction electrons in graphene have an energy-independent velocity v, one would expect $\tau \geq L/v$. Here we calculate that $\tau < L/v$ at the Dirac point (= charge neutrality point) in a clean graphene sheet, and we interpret this result as a manifestation of the Hartman effect (apparent superluminality) known from optics.

Piezoconductivity of gated suspended graphene

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We investigate the conductivity of graphene sheet deformed over a gate. The effect of the deformation on the conductivity is twofold: The lattice distortion can be represented as pseudovector potential in the Dirac equation formalism, whereas the gate causes inhomogeneous density redistribution. We use the elasticity theory to find the profile of the graphene sheet and then evaluate the conductivity by means of the transfer matrix approach. We find that the two effects provide functionally different contributions to the conductivity. For small deformations and not too high residual stress the correction due to the charge redistribution dominates and leads to the enhancement of the conductivity. For stronger deformations, the effect of the lattice distortion becomes more important and eventually leads to the suppression of the conductivity. We consider homogeneous as well as local deformation. We also suggest that the effect of the charge redistribution can be best measured in a setup containing two gates, one fixing the overall charge density and another one deforming graphene locally.

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Long-time photoluminescence in quantum dots

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One of the remarkable experimental characteristics of the so called blinking of the quantum dots is their power-law distribution of the lengths of the on (off) periods during which the photoluminescence is on (off). The power law-time characteristics do not seem to be rare in the zero-dimensional systems. We want to pay attention to another effect, in particular, to the theoretical interpretation of the experimentally observed power-law time dependence of the decay of photoluminescence of a quantum dot sample after excitation by a laser pulse. The luminescence response of certain quantum dot systems to a short laser pulse has been experimentally found to be a slow process, developing in time as a power-law dependence, in contrast to the perhaps usually expected exponential decay. In the presentation our attention will be payed to this particullar effect. We bring theoretical arguments in favour of the interpretation that the power-law decay can be basically a single-dor property. We use certain rather realistic model for this purpose. The model consists of a single quantum dot with electron-LO-phonon interaction, which is included as a non-adiabatic influence of the atomic lattice motion on the electrons inside the quantum dot. The relation of the present model of the quantum dot kinetics to real systems observed in experiments is discussed. The properties of the system are analyzed numerically.

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Relaxation to equilibrium in macroscopic quantum systems

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An isolated macroscopic system eventually approaches to equilibrium. In thermodynamics, this would be regarded as a relevant choice of the microscopic model and quantity of interest. But microscopic justification of the relaxation is a long standing fundamental issue of statistical mechanics. Indeed there are several explanations of thermalization depending on the quantities to be assumed macroscopic. Recently it has been pointed out that majority of the pure states in the Hilbert space are regarded as equilibrium states. Then it is reasonable to expect that the initial nonequilibrium state reaches a more p robable state of equilibrium. In this presentation, we explain how the relaxation dynamics can be made quantitative. We insist that the expectation values relaxes to a microscanonical average. The initial microcanonical state is externally perturbed for a transient duration and then left untouched. Our assumptions are that we are concern with quantities which polynomically depends on the system size, and the initial state is microcanonical state or unitary transformation of it. Numerical analysis for many body systems shows good agreements with the theoretical evaluation of matrix elements. Important points are that the relaxation occurs for microscopic quantities, and the actual density matrix after the waiting time deviates from the microcanonical state. Also, the so called Poincare recurrence is avoided since the initial state is equilibrium.

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Formation of mesoscopic Si wire by dislocation

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Mesoscopic Si wire is a useful material for micro- or nanoelectromechanical and micro- or nanooptical systems. This wire is generally formed only on the Si surface and not above it. In this study, we fabricated Si wire that floats above the Si wafer. The starting material was a p-type, (100)-oriented Si wafer. Si wire was fabricated by forming a dislocation in the wafer. The dislocation was formed by fabricating a groove on the surface using a tungsten carbide tip. This wafer with the dislocation was anodized in HF solution. The sample was observed by FE-SEM and FIB (JIB-4600F, JEOL) and by TEM (JEM-1400, JEOL). The width and depth of groove were about 10 μm and about 0.1 μm respectively. The dislocation occurred along the (111) crystal axis. The thickness of this wire was about 5 μm. A needle-shaped surface was formed under the wire, and a bridge girder structure was formed between the wire and wafer surface. The shape of the cross section of the wire was an inverted triangle, and the wire had a double-layered structure. The upper layer in this structure was porous, and the lower layer was crystalline (i.e. the structure was a hybrid structure). Progress has been achieved in the use of this wire with a hybrid structure. In our opinion, we are quiet certain that in the near future, electromechanical and optical systems will be developed through our research method. This work was partly supported by the Research Institute for Science and Technology of Tokyo Denki University, under Grant Q09-06.

Quantum models of energy transfer from electrons to protons in electron-driven proton pumps

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We discuss quantum-mechanical models of energy transfer from electrons to protons in various electron-driven proton pumps. These pumps, located in the inner membrane of the mitochondria in the living cells, carry protons against the electrochemical potential creating and maintaining the proton gradient, which is used thereafter for the adenosin triphosphate synthesis. We describe this system using approaches from condensed matter physics, starting from the effective Hamiltonian written in terms of electron and proton creation/annihilation operators. This Hamiltonian includes the energies of several electron/proton sites, their couplings to corresponding reservoirs, interaction with the environment, as well as electron-electron, proton-proton, and electron-proton (on-site and inter-site) Coulomb couplings, with the electron-proton Förster term being of special interest. During the resonant Förster process, an electron moves from a higher-energy state to a lower-energy one; whereas a proton jumps from a lower-energy state to the higher-energy one. The same mechanism is responsible for the fluorescence resonant energy transfer (FRET) in biological systems, as well as for exciton transfer in condensed matter. It should be noted, however, that in these processes the electron-hole system is involved, instead of the electron-proton pairs in our system. Using this Hamiltonian, we derive and solve numerically the master equation for the density matrix, which allows us to obtain the electron and proton currents through the structure. Studying voltage and temperature dependences of these currents, we determine the range of parameters where the pumping of protons is possible, and show that it is the Förster process which is responsible for the energy transduction from the electron to proton subsystems.

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Engineering the environment: Quantum circuit and universal thermalization

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We investigate a quantum circuit model of quantum dissipative dynamics aimed at achieving thermal equilibrium for an arbitrary qubit (two-level) system without making use of control ancilla for the system's evolution, which is often used in other methods for thermalization such as Quantum Metropolis. The goal is to construct a quantum circuit consisting of one system qubit and many environmental qubits that mimics the effects of a bath, and takes an arbitrary initial state to its canonical distribution at some temperature for any Hamiltonian of the qubit system.

Inspired by the derivation of the Lindblad form of the master equation in the Born-Markov approximation, we consider a quantum circuit given by iterations of a free evolution of the system Hamiltonian and interaction between the system qubit and the environment qubits. We show that for a single qubit system, this type of quantum circuit achieves dynamics leading to the canonical distribution of the system if we choose an appropriate number of iterations, the timing of free evolution, and the dimension of the environmental qubits.

To understand the importance of "memory effects" in the environmental system, where system information is fed back and spread over the environmental qubits before the next interaction, we analyze a quantum circuit that disallows such effects by refreshing the environmental qubits after each system-bath interaction. Although this type of circuit seems to model the Born approximation, we show that it cannot achieve a state in which the diagonal elements are given by a canonical distribution, even when the off-diagonal elements are not necessary zero. This theorem can be shown by the property of the CPTP map on a qubit system[1-2], which can represent any effect of the system-environment interaction reduced to the system. We also show that this model cannot achieve a canonical distribution (with no off-diagonal elements) for any continuously and injectively obtained effective system Hamiltonian.

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What John Bell would have to say about the idea of quantum computing?

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David Mermin expresses in [1] heartfelt regret that we are deprived the possibility to know about Einstein's reaction to Bell's theorem and Bell's reaction to "the quantum computation revolution of the 1990's". Indeed, it is very great loss. But both Einstein and Bell have expound enough clear their opinion about quantum mechanics in order one can conjecture their reaction to the idea of the quantum computation. For Bell the violation of the Bell's inequalities was "the real problem with quantum theory: the apparently essential conflict between any sharp formulation and fundamental relativity" [2]. Einstein has revealed this essential conflict in the description as far back as 1927. Therefore his reaction to Bell's theorem would be the same as Bell himself. The real problem with quantum theory, about which Bell told [2], is described with the EPR correlation [3] or the term "entanglement of our knowledge" coined by Schrodinger [4]. Ironically, this principle, introduced in order to prove that quantum mechanics can not be considered as complete description of physical reality [3], has become the basic idea of a real device, quantum computer. It could be possible because most modern physicists misinterpret the violation of the Bell's inequalities rather as the corroboration of the orthodox quantum mechanics [5] than "the real problem with quantum theory" [2]. This misinterpretation is a consequence of the lack of understanding by most modern physicists the positivistic essence the orthodox quantum mechanics and fundamental difference between be-able and observ-able [6]. Bell understood this difference. Therefore his reaction to the idea of quantum computing would be sceptical.

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P66

Why the persistent current can not decay in spite of the energy dissipation

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An electrical current induced in a resistive circuit should rapidly decay in the absence of an applied voltage. But the persistent current observed in superconductor [1,2] and normal metal [3] rings does not decay in magnetic field constant in time in spite of non-zero resistance. The preposterous claim by the authors [3,4] that this electrical current can flow without energy dissipation in realistic metal rings containing atomic defects, grain boundaries, and other kinds of static disorder is senseless [5] because of its contradiction with the experimental results [3] and the observations of the persistent current flowing against electric field [6]. The mysterious observations [1-3,5,6] can be described without this preposterous claim if one takes into account the change of angular momentum of electrons or superconducting pairs at the closing in the ring of the wave function describing their states. These changes because of the quantization compensate the changes because of the dissipation force. The quantum force introduced in [7] as the momentum change because of the quantization in a time unity provides formally the force balance at the description of the mysterious phenomena [1-3,5,6]. The essence and the method of logical deduction of the quantum force [7] do not overstep the limits of the universally recognised quantum formalism [8]. According to [7,8] the persistent current observed at non-zero energy dissipation is a direct (non-chaotic) Brownian motion which can be observed thanks to the discreteness of permitted state spectrum of superconducting pairs or electrons in mesoscopic rings and because of the Aharonov - Bohm effect.

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Size-induced synchronization in a coupled noisy system

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In this poster we investigate the role played by the system size in the phenomenon of stochastic synchronization between switching events and an external driving. In order to do that, we consider an ensemble of coupled nonlinear noisy oscillators driven by a periodic force, and introduce an output frequency associated to a collective variable of the system. By studying the dependence of this output frequency on the system size, we find that there exists a size-induced frequency locking.

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The effect of mechanical resonance on Shapiro steps in Josephson junction

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We study theoretically dynamics in a Josephson junction coupled to a mechanical resonator. Such system can be realized experimentally as a suspended ultra-clean carbon nanotube brought in contact with two superconducting leads. A nearby gate electrode can be used to tune the junction parameters and to excite mechanical motion. We augment theoretical estimations with values measured in samples fabricated.

We show that charging effects in the junction give rise to a mechanical force that depends on superconducting phase difference. The force can excite the resonant mode provided the voltage across the junction matches the resonant frequency. We develop a model that encompasses the coupling of electrical and mechanical dynamics. Our main focus is the effect of mechanical motion on Shapiro steps developed in a d.c. and a.c. biased junction. We demonstrate that the upper and lower current of Shapiro steps are modified by mechanical motion. This can be used for experimental detection of the motion.

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Signatures of the transition from quantum to classical behavior in a nonlinear NEMS

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The transition between a system behaving completely classically and behaving completely quantum-mechanically is complicated. The two kinds of behaviors can be very different particularly when the system is nonlinear. We know the transition depends on the size of the system, the temperature and environmental effects, and on the nonlinear dynamics, so it is a multi-parameter landscape. But what is the shape of this landscape? We present evidence for non-monotonicity associated with chaos in the quantum-classical transition in a damped driven double-well oscillator, as well as the simple harmonic oscillator. We argue that experiments probing such a transition are within reach in nanomechanical systems, specifically in doubly-clamped beams under sufficient compression.

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P70

Quantum description of a time-dependent mesoscopic RLC circuit

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We present a comprehensive quantum description of a mesoscopic RLC circuit with time-dependent resistance, inductance and capacitance. On the basis of a quadratic invariant and the quantum invariant method, we solve the Schrödinger equation for the circuit and write the correspondig wavefunctions in terms of solutions of the Milne-Pinney equation. Afterwards, we use the quadratic invariant to construct coherent states and employ them to study quantum properties of the time-dependent circuit. In particular, we show that the product of the quantum fluctuations of the charge and the magnetic flux does not satisfy the minimum uncertainty relation.

Study of coherence effects in nano-electromechanical systems

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We study the properties of a nano-electromechanical system [1], modeled as a quantum dot linearly coupled to a mechanical oscillator, in the coherent regime, where the electronic and vibrational time scales are of the same order. In this situation the off-diagonal elements of the density matrix in the basis of the energy are important. Therefore we derive a generalized master equation in the sequential tunneling regime, and employ it to study the steady-state vibronic and electronic properties of the system [2]. Within the coherent regime, two different behaviors can be observed according to the system parameters. For intermediate frequencies, the system can be described by means of an effective thermal distribution with a lower temperature than the one of the environment. For still slower oscillations, a strongly coherent regime is entered with an even more important role played by the off-diagonal matrix elements which may lead to non-classical behavior. Exploring these regimes, a marked suppression of the vibron Fano factor [3], defined as the ratio between the variance and the mean vibron occupation number, is observed. It can even attain sub-poissonian values. Position and momentum variances together with the fluctuations of the charge on the dot, exhibit a qualitatively analogous decrease.

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A Bell test with the amplification of one entangled photon

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Investigating quantum features in the macroscopic regime is fundamentally important, because it allows to fully solve the conceptual difficulties of the quantum to classical transition, as pointed out by the famous Schrödinger's cat paradox [1]. However, the experimental exploration of quantum mechanics in the macroscopic domain is extremely challenging because multiparticle systems strongly interact with the environment and can easily and quickly lose their quantum coherence. Thus, the task of revealing the entanglement of multiparticle systems asks for measurement techniques difficult to define and which, if not sufficiently accurate, can lead to wrong conclusions. Some misinterpretations can occur in the experimental investigation of the entanglement between a photon and a macroscopic field which, in principle, can be created by amplifying one photon initially belonging to an entangled pair via a phase covariant cloner [2].

We present a Bell test where one photon of an entangled pair is amplified by a completely classical machine, a Measure and Prepare cloner, and then detected by threshold detectors, whose signals undergo a postselection that is independent of the measurement basis [3]. A CHSH inequality can be measured after the amplification. Unlike standard CHSH test, the choice of the measurement basis is made after the optical amplification. We show that a violation of the Bell inequality is surprisingly possible, although the final micro-macro state is fully separable. Therefore, the violation of the CHSH inequality, as of other entanglement witnesses, in the presence of postselection, cannot be considered as an indication of the entanglement in a bipartite micro-macro state. For postselection we mean the selection of the events after detection, the losses in the system, finite detection efficiencies and similar effects.

This result highlights the relevance of the detection loophole, opened by postselection: ignoring this loophole can lead to dangerous misinterpretations in the scenario of Schrödinger's cat experiments.

By using threshold detectors and postselection, one can only infer the entanglement of the initial pair of photons, so micro-micro entanglement [4]. Detecting photonic micro-macro entanglement in the presence of losses with currently available technology remains an open question.

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One dimensional ratchet potential and collisions

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When studying the mechanism of one-dimensional transport in a ratchet potentia of interacting particles, usually such collisions between particles are neglected.

This would be correct if the particles are indistinguishable and indentical, but when the particles are not identical and/or distinguishable the hard core interaction should be taken into account The main objetive of our contribution is to analyze this effect in the transport mechanism.

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Quantum memory at resonant Fermi edges: Shot noise evidence in quantum dots

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The interaction of conduction electrons with localized perturbations leads to the Fermi-edge singularity effect, which was first predicted theoretically for X-ray absorption in metals [1] and later verified experimentally [2]. The same theory [1,3] has been used to describe similar situations, such as resonant tunneling through localized levels, always leading to a characteristic power-law divergence. The proper description of the transport set-up is done by an extension of the original Fermi-edge singularity model, where no charge transfer between the continuum and the localized level is considered, to the interacting resonant level model, which has served recently as an important benchmark for novel quantum transport techniques [4].

The Fermi-edge singularity in transport through quantum dots occurs in the regime where the quantum dot level energy is similar to that of one of the leads. The change of occupation in the local level during the tunneling process leads to sudden changes in the scattering potential and hence, to truncated singular behavior of the current through the quantum dot at resonance and power-law dependence away from resonance [5,6]. As shown in recent experiments [6], noise in this regime displays characteristic behavior which cannot be accounted for by the Markovian theory. Since the Fermi-edge singularity transport setup involves both many-body correlations and quantum coherence it is reasonable to expect large non-Markovian corrections in the singularity region. We show that this is indeed the case, and that including the non-Markovian effects allows us to account for all of the qualitative features of the noise.

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Single-electron heat diode

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We propose a new functional nanoscale device, a single-electron heat diode [1]. It consists of two semiconductor quantum dots or small metallic islands, coupled by tunnel contacts to two electron reservoirs at different temperatures. Each dot is coupled to just one reservoir, and there is no tunneling between the dots, so that electrons cannot be transported through the system. However, due to the interdot Coulomb interaction, electrons hopping in and out of dots can exchange energy, allowing heat to flow from one reservoir to the other. This type of heat transport mechanism was previously studied in Ref. [2].

In a heat diode energy can flow through the system when one of the reservoirs is cold and the other one is hot, but the flow is suppressed if the temperatures are reversed. To produce a diode effect with the present system, the double dot energy levels should have a particular structure which can be achieved by applying appropriate gate voltages. First, we must be able to truncate the system to the four lowest charge states, with dot occupations 00, 01, 10, and 11. Then the tunneling sequence $00 \rightarrow 10 \rightarrow 11 \rightarrow 01 \rightarrow 00$ transports a heat quantum, equal to the Coulomb interaction energy, between the reservoirs. The time-reversed cycle naturally carries the same quantum in the other direction. These cycles are the only way heat can be exchanged between the reservoirs.

For the diode effect an asymmetry in the level structure is required. If the charging energies for hopping into the left dot are of the same magnitude as the low temperature and the energies for the right dot are of the same magnitude as the high temperature, then the transport cycle is only allowed with the right reservoir at the high temperature. With a reversed thermal bias, the low-temperature electrons in the right reservoir do not have enough energy to tunnel into the dot and the heat-transport cycle is exponentially suppressed, producing a very efficient diode behavior. For experimentally realistic parameters it is possible to have a forward heat current of the order of 1 fW with the reverse current being a few percent of the forward value. This asymmetry is much larger than what can be obtained with any previous realistic heat diode proposal.

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Thermodynamics of single-file diffusion

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We investigate a one-dimensional diffusive motion of a system of interacting Brownian particles driven by an external time-dependent force. We assume the hard-core interaction between the particles, the spatially restricted dynamics (reflecting boundary), and the harmonically oscillating driving force. Comparing to the corresponding model without the inter-particle interaction, the inter-particle interaction induces additional entropic repulsive forces and, consequently, it also affects the energy transformations during the motion. Particularly, in the two-particle problem, we have found out an increase (decrease) of the mean work done on the right (left) particle. This interaction-caused asymmetry also influences the one-particle mean position, the one-particle mean entropy production, and the mean heat released to the bath. In the stationary regime, we present an exact analysis of these new interaction-induced features and we discuss their dependence on the model parameters. Resonance-like maxima have been detected if we plot the work accepted by the individual particles during one period of the external driving as the function of the driving frequency. The mean entropy production exhibits a maximum both as the function of the diffusion constant (i.e., of the bath temperature) and as the function of the driving frequency. In fact, the mean entropy production is a symmetric function of these two model parameters.

g-factor anisotropy of hole quantum wires induced by the Rashba interaction

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We present calculations of the g factors for the lower conductance steps of 3D hole quantum wires. Our results prove that the anisotropy with magnetic field orientation, relative to the wire, originates in the Rashba spin-orbit coupling. We also analyze the relevance of the deformation, as the wire evolves from 3D towards a flat 2D geometry. For high enough wire deformations, the perpendicular g factors are greatly quenched by the Rashba interaction. On the contrary, parallel g factors are rather insensistive to the Rashba interaction, resulting in a high g factor anisotropy. For low deformations we find a more irregular behavior which hints at a sample dependent scenario.

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Counterfactual process in weak value

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The counter-intuitive phenomena in quantum mechanics are often based on the counter-factual (or virtual) processes. The famous example is the Hardy paradox, which has been recently solved in two independent experiments. Also, the delayed choice experiment and one of quantum descriptions of the closed time like curves can be also examples of the counter-intuitive phenomena. The counter-factual processes can be characterized by the weak value [1] initiated by Yakir Aharonov and his colleagues. In this talk, I will introduce the weak value from the probability theory and the connection to the counter-factual processes in these examples [2,3].

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P79

Discrete time quantum walk as stochastic process in quantum mechanics

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Quantum walks (QWs), which are defined from the quantum mechanical analogue of the random walk [1], have a great potential to develop various fields like quantum information sciences and the quantum foundations as same as the random walk, for instance, constructing the efficient quantum algorithm design, realizing quantum phase transition, and explaining the effective energy transfer system for the biomolecules such as the photosynthetic systems. The important properties of the QW are a inverted-bell shaped limit distribution and a diffusing time like the ballistic transport, that is, this is faster than the random walk, see more details in Refs. [2-4]. By comparison to those of the (classical) random walk, we explain how the quantum speedup occurs. To show the time-symmetric property on the state in the quantum walk, we construct the stochastic model using the weak value initiated by Aharonov and his company. The important properties on the weak value are to construct the non-contextual probability space, which means observable independent probability space, and the experimentally accessible quantity. The quantum walk can be taken as the stochastic process in the non-contextual probability space using the weak value [5]. The set of the weak values on the position and coin for each step means the random variables on the stochastic process. Since this quantity converges to the scaling time t, we can speed up these algorithms. However, when we take the periodic measurement, the convergence time scale continuously changes to root of t, which corresponds to one of the random walk [6]. Since we can obtain the weak values by employing weak measurement many times, the weak value must be counter-factual. The speedup in the quantum walk results from the time symmetric property by the counter-factuality on the quantum states [5]. In this contribution, we will present the review of the quantum walk, how we explain the quantum speedup in the quantum walk algorithm, and their related topics on the decoherence [7,8].

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Second Josephson oscillations beyond mean-field: Quantum–classical correspondence and break-down

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A simple four-mode Bose-Hubbard model with intrinsic time-scale separation can be considered as a paradigm for mesoscopic quantum systems in thermal contact. Bogoliubov excitations of the two-mode subsystems behave similarly to second sound phenomena in liquid Helium II, performing second Josephson oscillations [1]. This system has recently also been investigated in the high-amplitude regime, predicting equilibration and quantum thermalization [2]. We will illuminate the beyond-mean-field regime, discussing quantum-classical correspondence and the range of validity of the second Josephson theory.

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Real-time renormalization group in frequency space with normal and superconducting leads

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In this contribution we generalize the real-time renormalization group in frequency space (RTRG-FS) technique to quantum systems in contact with superconducting leads. The RTRG-FS is a formally exact perturbative renormalization group scheme in Liouville space from which the kernel of the kinetic equation for the reduced density matrix can be calculated. The method is applicable for small quantum systems, such as quantum dots, in contact with several particle or heat reservoirs. It is based on a perturbative expansion in the system-reservoir coupling, thus allowing for quantum systems with arbitrarily large interaction strengths. In its original form [1] the RTRG-FS was established for systems coupled to normal leads only. Here we consider a generalization of the method to the case where the leads may be both normal or superconducting. In the latter case transport can be maintained either by quasiparticle or Andreev tunneling giving rise to a rich variety of interesting physical phenomena. We demonstrate the method on an exemplary system of a quantum dot attached to one normal and one superconducting lead and discuss some further applications.

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Spin torque shot noise and magnetization dynamics

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We investigate the role of spin shot noise in the magnetization dynamics of mono-domain ferromagnets.

A spin polarized current may transfer angular momentum to a ferromagnet, resulting in the celebrated spin torque phenomenon [1]. The spin shot noise, associated with the discreteness of the spin degree of freedom, leads to a nonequilibrium stochastic force acting on the ferromagnet. We propose a stochastic version of the Landau-Lifshitz-Gilbert equation including both, thermal and nonequilibrium, sources of noise [2]. By means of the Keldysh technique we derive the spin shot noise correlator in the magnetic tunnel junction setup performing a perturbative expansion in terms of the tunneling amplitude and the spin flip processes. The correlator exhibits a dependence on the mutual orientation of the fixed and free layer's magnetizations, thus being fundamentally different from thermal noise. Another peculiarity is its dependence on the spin flip current, counting the total number of spin flips irrespective of their direction, as opposed to the spin current. We solve the corresponding Fokker-Planck equation and show that the spin shot noise leads to the experimentally observed nonmonotonic dependence of the precession spectrum linewidth on the current and to a saturation of the spectral linewidth at small temperatures.

Finally, we address the question of spin torque switching by applying a generalized Fokker-Planck approach that models the alteration of switching rates by a change of the effective temperature in the Arrhenius factor [3, 4]. We show that the spin shot noise leads to a renormalization of the effective temperature [4]. The details of the renormalization depend on the geometry of the system. In particular, the nonequilibrium noise may lead to the occurrence of "cold" and "hot" trajectories of the magnetization vector with respect to the noise intensity.

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Optimal teleportation from a noisy source

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Several studies have tackled the problem of teleportation when Alice and Bob share a non-maximally entangled state. Be that a pure or mixed state, protocols that aim to maximize the input/output fidelity have been suggested. Realistic experimental situations will nonetheless present decoherence not only in the quantum channel but also in the state to be teleported. We consider the problem of realistic teleportation of d-dimensional quantum states where neither the bipartite quantum channel nor the unknown input state are in a pure state. In the case of maximally entangled bipartite quantum channel a protocol that gives unit fidelity for pure and mixed input states can be easily established, but when the bipartite state undergoes a decoherence process knowledge of the space of states to be teleported is crucial to determine the optimal protocol. We study the case where this space of states is generated by a decoherence map applied to the space of pure states and we aim to maximize the fidelity between the teleportation output state and the original pure state. Our protocol only requires knowledge of the bipartite state and the decoherence channel that acts on the input states. Numerical results show that by taking this into account our protocol outperforms other protocols and the increase in fidelity can reach 10-20 % in many cases. Surprisingly we find that for several experimentally relevant decoherence processes, the standard teleportation can achieve the maximum fidelity. Quantum information is disturbed by the environment even before its transmission. Our results show that this disturbance cannot in general be accommodated as a faulty communication channel. Recognizing this is not only of conceptual importance, but has also practical implications. The teleportation protocol proposed appeals to this mindset shift in order to obtain sizable gains in communication quality.

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Nuclear spin diffusion in quantum confined semiconductor nanostructures

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We analyze the nuclear spin diffusion effect in semiconductor quantum wells in connection with dynamical nuclear polarization under optical pumping. The natural confinement provided by the particular geometry of quantum well structures is responsible for a position dependent nuclear spin relaxation time and a reduced nuclear spin diffusion. In particular, we consider the case of GaAs quantum wells within GaAlAs barriers and analyze the nuclear spin diffusion for As nuclei. Our results, obtained for different nuclear spin diffusion constants, show that nuclear spin diffusion has a relatively small effect on the overall polarization of As nuclei in these structures.

Spectrum of an electron spin coupled to an unpolarized bath of nuclear spins

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The main source of decoherence for an electron spin confined to a quantum dot is the hyperfine interaction with nuclear spins. To analyze this process theoretically we diagonalize the central spin Hamiltonian in the high magnetic B-field limit. Then we project the eigenstates onto an unpolarized state of the nuclear bath and find that the resulting density of states has Gaussian tails. The level spacing of the nuclear sublevels is exponentially small in the middle of each of the two electron Zeeman levels but increases super-exponentially away from the center. This suggests to select states from the wings of the distribution when the system is projected on a single eigenstate by a measurement to reduce the noise of the nuclear spin bath. This theory is valid when the external magnetic field is larger than a typical Overhauser field at high nuclear spin temperature.

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Quantum effect in opto-mechanical systems

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We study the *Von Neumann measurement model* under a new prospective. Introducing an externally adjustable parameter ϕ, a geometric phase can be attached to an harmonic oscillator and detected using the atomic degrees of freedom as an interferometric device. We extend our study to systems at finite temperature undergoing a dissipative Markovian dynamics. The scheme can be realize in opto-mechanical devices as well as in setups involving superconducting qubits coupled with nano-mechanical oscillator.

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Conservation relation involving multipartite entanglement in 4-qubit systems

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The question on wheter the dynamics of entanglement conceals a conservation law of such quantity is of particular importance in the establishment of the global laws governing the evolution and distribution of this physical resource. Even though paradigmatic processes in the production of entangled states - such as letting an initially excited atom to decay in a zero-temperature environment - preclude the possibility of identifying the entanglement between two interacting systems as a conserved quantity, some particular invariant relations involving entanglement have been found when considering certain kinds of multiparticle systems. In spite of the limitations of these results (they constitute examples mostly restricted to a specific transformation), they open the path to search for more general conservation laws that constrain the distribution of entanglement in multiqubit systems. In this work we take a step further in this direction by providing a dynamical invariant in terms of bipartite and multipartite entanglement contributions for a 4-qubit system, in which two initially entangled qubits interact locally with their corresponding environments by means of an arbitrary unitary transformation.

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Ultrafast dynamics of magnetic impurities in GaAs

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We study ultrafast dynamics of a magnetic impurity such as a Mn atom immersed in GaAs bulk host under the influence of strong laser pulses. The band structure of the host is treated in semi-realistic form via a tight-binding model and the influence of the driving field is treated exactly within non-equilibrium Green's functions formalism. The interaction of the local magnetic moment with itinerant electrons described by the $sp-d$ exchange model [1] is treated perturbatively at the mean-field, i.e. Hartree-Fock level. We solve numerically exactly the time evolution of various quantities of interest and analyze effects of different model parameters on the observed behavior. Planned extensions of this study to more elaborate treatment of interactions and/or inclusion of a finite concentration of impurities will be of direct relevance for current experiments on ultrafast demagnetization in the dilute magnetic semiconductor GaMnAs.

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Spin current and dynamics of an electron gas with Rashba spin-orbit coupling in the presence of magnetic disorder

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We consider a two-dimensional electron gas in an inversion asymmetry layer and in the presence of spatially distributed magnetic impurities. The electrons are subject to spin-orbit coupling produced by the inversion asymmetry, and to spin dependent scattering through the impurities. The spin-orbit effect splits the energy into two distinct chiral bands, proportional to the Rashba constant. The impurities are supposed in a paramagnetic state, introducing then a statistically homogeneous and isotropic perturbation to the electron motion. The electrons are coupled to the magnetic impurities by the exchange interaction. We adopted a tight-binding model, where the electrons can jump between nearest neighbors on a square lattice.

We investigate the spin transport together with the localization properties of the electrons as a function of the disorder using linear response theory and numerical simulations.

We compute the local and total density of states, the dynamical spin Hall conductivity and, by integration of the Schrödinger equation, the temporal evolution of the wavefunction. In the continuum limit, the spin Hall conductivity is obtained analytically, as a function of the Fermi energy, scattering time, and applied electric field frequency. At variance to the non-magnetic case, the intrinsic spin Hall effect is recovered in the clean limit.

The present system can be considered as a dilute magnetic semiconductor at a temperature above the ferromagnetic transition. In the ferromagnetic state, experiments show that the local density of states possesses a fractal structure. We also find, although we limit our study to the paramagnetic state, a "metal-insulator" transition and an intermittent spatial distribution of the electron probability in the disorder dominated regime. The transition from a delocalized to a localized regime, when the disorder increases, is accompanied by a modification of the spreading and geometry of the wavefunction. We measure the temporal asymptotic behavior of the wavefunction width and its fractal dimension. We observe a drastic change in the frequency dependence of the spin Hall conductivity.

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What is nature?

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This paper presents an ontological view of mathematics connecting the foundations of mathematics to the foundations of physics. Three main questions are explored: 1) Are nature and mathematics intrinsically related to one another? 2) If they are, what are the bases for that intrinsic relationship? 3) Further, if such a relationship exists, what exactly is its character? Both physics and mathematics are based upon observations of nature. The problem with this is that the human scale observations which lie at the bottom of the mathematical architecture have been rendered obsolete by recent, refined, and enlarged observations which have been enabled by technology. These observations, primarily of photon behaviour (but also cosmological observations), reveal a previously unquantified interconnectedness of nature at fine scales. These recent physical discoveries have changed our view of nature and our mathematical concepts are also affected. This necessitates a reappraisal of certain fundamental mathematical concepts which were established millennia ago. The affected notions are, in particular, those upon which the concepts of continuity and limit-approach are based. These are examined in detail. In order to establish a firm basis for these ideas, five important experiments exhibiting the superposition and entanglement behaviours of photons in mazes are cited. Photons exhibit responsiveness to a wide-area spatial and temporal environment. At present we have no explanation for the mechanics of these important phenomena. These responses require constantly varying information that is necessarily encoded in some form of fine-grained activity. This implies the existence of a carrier field, an active continuum. A connection to the mathematical continuum is then made by noting that geometrical form is described numerically. Reversing this we may say that enumeration can be viewed as being encoded geometrically. Nature is active form and this form, viewed infinitesimally, has a unique realization that encodes certain mathematical principles. The unique form is shown to be the source of minimal entropy. Exactly how this evolves is developed in detail.

The description of limit activity involves the prime numbers which form a ‘strict (intrinsic) identity group’ with pi and e. It is shown that both pi and e are derivative from primeness. The required structure of the active infinitesimal is developed as a Clifford-Hopf bundle. These ideas explain Euler’s identity and lead to a method of validation for Riemann’s hypothesis.

The main consequence of this paper is a mandate to move the observational bases of mathematics, from their present grounding, to a grounding in observations which are more recent and which contradict those which form the present grounding. This will restructure the limit concept and affect other areas of mathematics. Several of these effects are noted in detail and the changes these things require in the structure are shown. The result is a mathematical concept that is consistent with our knowledge of nature, and hence intrinsically joined with a physical concept.

Duality of the quantum competing systems

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In recent years, advances in microfabrication technology, various quantum dot array system can be manufactured. Our main aim in this study, such ferromagnetic-superconductor quantum dot array, is to build a theoretical basis using the quantum competing system with each other. In a case of $E_j \gg E_c$, there act as Josephson network systems using the quantum magnetic flux tunneling. On the other hand,case of $E_c \gg E_j$, there act as Coulomb blockade systems using the Cooper-pair tunneling. The quantum vortex and the Cooper-pair is known that the duality relation to each other. Therefore, these two systems can be understood as a dual systems with each other. In such a system, we assume that the duality conditions, as follows:

$$V \equiv \tilde{I}, \ \tilde{V} \equiv I. \tag{7}$$

where V and I describe voltage and current of Cooper pair respectively, and $\tilde{V}$ and $\tilde{I}$ describe voltage and current of vortex respectively. From the above conditions, we derived the following relationship:

$$N_{\mathrm{c}}(x) = \frac{1}{2\pi} \sin \tilde{\theta}(x), N_{\mathrm{v}}(x) = \frac{-1}{2\pi} \sin \theta(x). \tag{8}$$

where $N_{\mathrm{v}}(x)$,$N_{\mathrm{c}}(x)$ describe number operator of vortex and number operator of Cooper pair respectively, and $\theta(x)$, $\theta(\tilde{x})$ are phase of Cooper pair and phase of vortex respectively. These the commutation relations is given by

$$[\, N_{\mathrm{c}}(x_a), \theta(x_b)\,] = \mathrm{i}\delta_{a,b}, \left[\, N_{\mathrm{v}}(x_a), \tilde{\theta}(x_b)\,\right] = \mathrm{i}\delta_{a,b}. \tag{9}$$

Our main results are listed below.

1. Based on such a dual system,we proposed the model of quantum competing system and studied the dual transformation.

2. We derived Ginzburg-Landau field theory in quantum competing system and studied the statistical mechanics.

We are going to discuss the quantum phase transition behind these quantum competing system, and will show the theoretical conditions to control these system.

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Spin-orbit driven spin transfer torque in uniform nanomagnets

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Spin-orbit driven spin transfer torques (SO-STT) have only been recently predicted and observed in experiments on metallic and semiconductor uniform magnetic nanostructures. In the case of SO-STT, an electrical current passing through a nanomagnet induces an additional spin polarization of the carriers via spin-orbit coupling. This additional current-induced magnetic moment of the carriers couples via exchange interaction to the magnetization of the ferromagnet which is thus re-oriented. SO-STT has the potential to become an invaluable tool for magnetic control and characterization [1] of the uniform nanomagnets. However, in contrast to the situation of spin-transfer torques in noncollinear magnetic structures, both theoretical understanding and practical applications of SO-STT are only at the beginning. We unify the current theoretical approaches to investigating SO-STT and provide a detailed theoretical study of the effect by calculating the current-induced fields (CIF) responsible for magnetization re-orientation in the case of ferromagnetic semiconductors. Our theoretical analysis is applied to strained GaMnAs nanomagnets and predicts how the magnitude and symmetry properties of CIFs depend on semiconductor parameters such as strain, disorder, and carrier density or magnetization and nanomagnet orientation. We have used our results to help interpret the experimental data in a recent application of SO-STT that introduced spin-orbit driven ferromagnetic resonance [1] as a novel nanoscale characterization technique for uniform ferromagnets.

[1] D. Fang, H. Kurebayashi, J. Wunderlich, K. Vyborny, L.P. Zarbo, R.P. Campion, A. Casiraghi, B. L. Gallagher, T. Jungwirth, A.J. Ferguson, Spin-orbit-driven ferromagnetic resonance, arxiv:1012.2397.

Phase transitions in the Falicov-Kimball model away from half-filling

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The canonical Monte-Carlo method is used to study the order-disorder phase transition in the Falicov-Kimball model away from half-filling. It is shown that the transition from various inhomogeneous ground-state phases to the disordered phase can be either direct or indirect. The indirect transition means that the ground-state phase changes to a different ordered phase with the increasing temperature. It is shown that the Falicov-Kimball model, depending on the ground state phase, undergoes first order or second order phase transition or can even undergo both for the same parameters and different temperatures if the transition from the ground-state phase to the disordered phase is indirect.

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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. During 2010, the rooms of the hotel were modernized. The hotel offers a wide selection of conference services.

The 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 tram No. 22 which has its stops nearly in front of the Pyramida Hotel: Prague Castle within about 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 about 25 minutes ride.

Wallenstein Palace

Wallenstein Palace (Valdštejnský palác) is situated in the very center of the Lesser Town 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 ‘Prague Castle and Wallenstein Palace’.
Special tram will depart from the Pyramida Hotel to the Malostranská station on Monday afternoon to facilitate FQMT’11 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 tram No. 22 (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 ‘Prague Castle and Wallenstein Palace’.

St. Simon and Juda Church

St. Simon and Juda Church (Kostel sv. Šimona a Judy) was built by the Czech Brethren between 1615 and 1620. After the battle of the White Mountain (1620) the Brethren 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 Čechův most (Čech Bridge) tram

stop on Tuesday afternoon to facilitate FQMT'11 participants transfer. Exact departure time will be announced during the Conference.

For those who will use an individual transfer: The easiest way from the Pyramida Hotel is to reach the Malostranská stop by tram No. 22. Here, you just cross the rails and ride, from the opposite tram platform, by tram No. 12. to the stop Čechův most (one stop). Then, crossing the Vltava River on foot, you will reach the St. Simon and Juda Church within 7-10 minutes - see the map 'Places of the Public Lectures'.

Alternatively, e.g. if you prefer to have a dinner in some restaurant located in the Old Town area, you can reach the St. Simon and Juda Church from the Malostranská station by 15-20 min walk. In such a case, we recommend to cross the River using the Mánesův most (Mánes Bridge). Public transport can also be used for your transfer across the River (bus X-18, 15 min interval) and in the Old Town (bus No. 133, 7-8 min interval in late afternoon) - see the map 'Places of the Public Lectures'. Underground (metro) line A connects both river banks (Malostranská and Staroměstská stations) as well.

Rudolfinum

The Rudolfinum was built in neo-renaissance style in 1880's. It was originally designed as the House of Artists, in the beginning of the Czechoslovak Republic it was a seat of its Parliament, and from 1946 the Czech Philharmonic Orchestra has resided here. Dvořák's Hall of Rudolfinum is supposed to be the best Prague concert hall. Numerous classical music concerts, including events of the famous Prague Spring Festival take place there.

How to get there:

Special tram will depart from the Pyramida Hotel to the Malostranská tram stop on Thursday afternoon to facilitate FQMT'11 participants transfer. Exact departure time will be announced during the Conference.

For those who will use an individual transfer: The best way from the Pyramida Hotel is first to reach the Malostranská stop by tram No. 22. From this stop you can cross on foot, within 5-7 minutes, the Vltava River using the Mánesův most (Mánes Bridge). At the end of the bridge you will reach the Palachovo náměstí (Palach Square). The Rudolfinum building is located on the left side of this square. Alternatively, the River can be crossed by bus X-18 (runs in 15 min interval) or by underground (metro) line A (from Malostranská to Staroměstská stations) - see the map 'Places of the Public Lectures'.

Prague Castle (St. Vitus Cathedral, Vikárka Restaurant)

The **Prague Castle**, the ancient seat of Czech sovereigns, now the seat of the president of the Czech Republic, is the most important historical and cultural place of Prague. Its palaces, Saint Vitus Cathedral and churches situated at the hill above the Vltava River represent the symbol of the Czech Lands. These palaces, gardens and churches create the largest castle complex in Europe. You can read more about the Prague Castle in various books on the European and Czech history besides much special literature devoted just to the Prague castle, its history and architecture.
St. Vitus Cathedral (St. Vitus, St. Wenceslas and St. Adalbert Cathedral in full name) has been always considered to be the most important church of the Czech lands and intimately related to the history of the Czech state. The coronations of Czech kings took place in it, and many kings are buried there.
Name of the **Vikárka Restaurant** is related to the former seat of the ecclesiastical vicariate in this place; tradition of the restaurant started in the period of Charles IV (14th century) who yielded the vicars right to brew beer. The conference dinner will be held mainly in the beautiful old part of the Vikárka Restaurant called Rudolph's foundry.

How to get there:
You can reach the Prague Castle (see maps 'Nearest neighborhood of the Pyramida Hotel' and 'Prague Castle and Wallenstein Palace'):

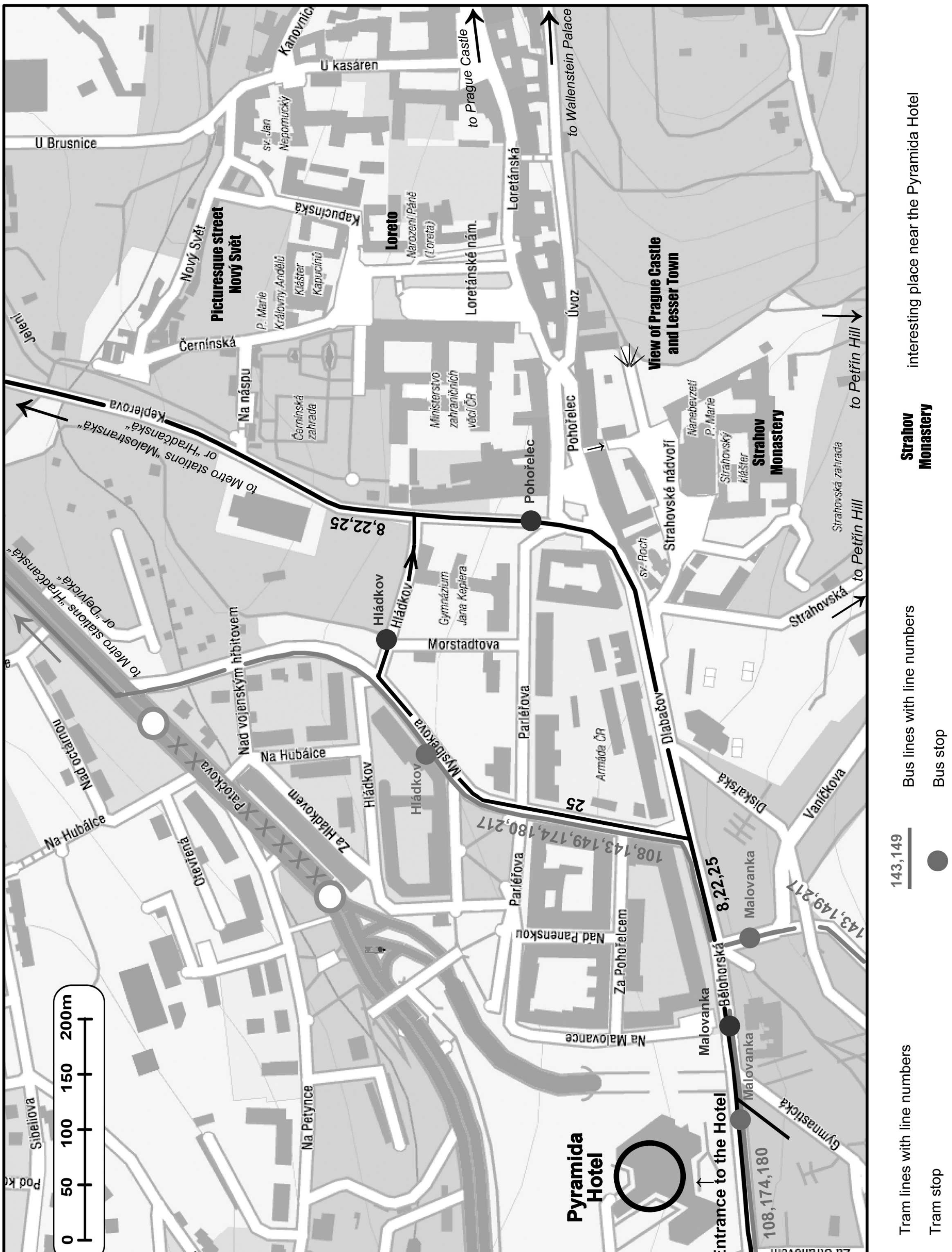
1. either by about 25 minutes walk, starting down along the Bělohorská street (the main street where the Pyramida hotel is situated)
2. or by trams No. 8 or No. 22 (1 stop, about 2 minutes) down along Bělohorská street from the stop Malovanka to the stop Pohořelec, from where you can reach the Prague Castle within 15 minutes walk
3. or going by tram No. 22 two more stops beyond the stop Pohořelec (3 stops and 5 minutes in total) to the stop Pražský Hrad from where you can reach the central part of the Prague Castle within 7 minutes walk from the different side.

Both the St. Vitus Cathedral and Vikárka Restaurant are situated in the central part of the Prague Castle - very near each to other.

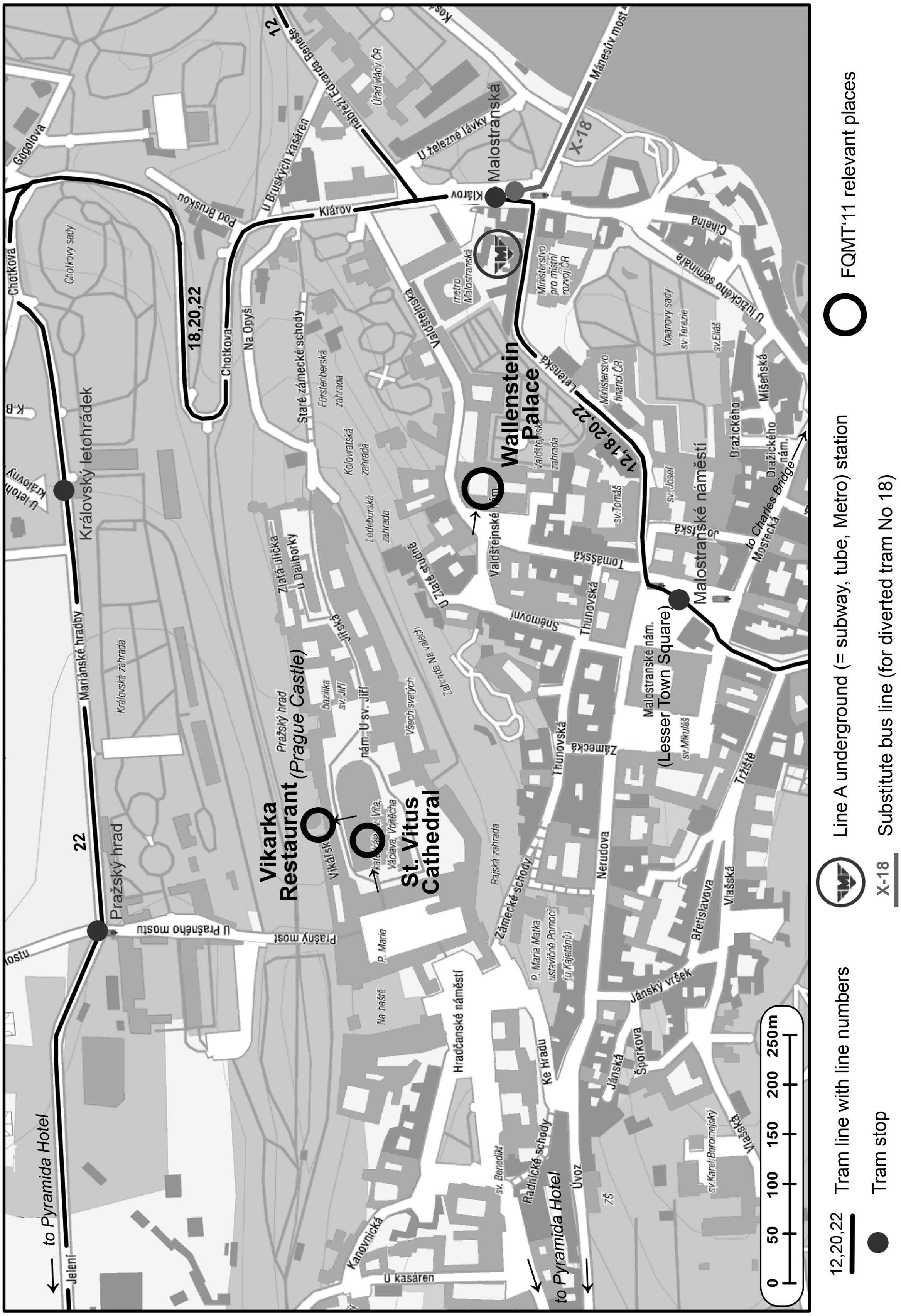
Maps

Prague center

Pyramida Hotel - access and nearest neighborhood



Prague Castle and Wallenstein Palace neighborhood



Places of the Public Lectures