ICTP Workshop on Driven Quantum Systems

Nov. 28 - Dec. 2 2016
San Carlos de Bariloche
Argentina

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	Sunday 27	Monday 28	Tuesday 29	Wednesday 30	Thursday 1	Friday 2
8:45-9:00		**Opening**				
9:00-9:45		**Zoller**	**Blais**	**Fazio**	**Amo**	**Paz**
9:45:10:30		**Petta**	**Doherty**	**Schön**	**Chanelière**	**Serra**
10:30-11:00		Coffee break				
11:00-11:45		**Schmidt-Kaler**	**Foa Torres**	**Pastawski**	**Ludwig**	**Fainstein**
11:45-12:15		**Cormick**	**Valenzuela**	**Muller**	**Kiselev**	**Closing**
12:15-14:30		Lunch				
14:30-15:15		**Molenkamp**	**Lyon**	**Free**	**Kohler**	
15:15-16:00		**Rudner**	**Arrachea**		**Perfetti**	
16:00-16:30		Coffee break	Coffee break		Coffee break	
16:30-17:15	17:00-19:00 **Registration**	**Oliver**	**Gefen**		**Tabosa**	
17:15-17:45		**Feinberg**	**López**		**Moya-Cessa**	
	19:30 **Welcome reception**	**Free for discussion**	18:00-20:00 Poster Session (with snacks+ beer)		**Álvarez**	
					Free for discussion	
20:30		Dinner	Dinner	Dinner	**Workshop dinner**	

TALKS DQS2016

Monday morning session I

Chairperson: M. Kiselev

Mon 28, 09:00 am

T1 – Nano-Scale 'Dark State' Optical Potentials for Cold Atoms

M. Lacki, M. Baranov, H. Pichler, P. Zoller
Institute for Theoretical Physics, University of Innsbruck, and Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, Innsbruck, Austria

Optical potentials generated by laser light are a fundamental tool to manipulate the motion of cold atoms with both conservative and dissipative forces. Paradigmatic examples of conservative optical potentials are optical dipole traps from a focused far off-resonant light beam, or optical lattices generated by an off-resonant standing laser wave, as basis of the ongoing experimental effort to realize atomic Hubbard models. The underlying physical mechanism is the second-order AC Stark shift of an electronic atomic level, which is proportional to the light intensity. Optical potential landscapes, which can be designed, will thus reflect, and be limited by the achievable spatial variation of the light intensity. For light in the far-field, i.e. for optical trapping far away from surfaces, this spatial resolution will thus be given essentially by the wavelength of the light. In the quest to realize free-space optical subwavelength structures for atoms we will describe and study a family of conservative optical potentials, which arise as non-adiabatic corrections to dark states in atomic ?-type configurations, building on the strong non-linear atomic response to the driving lasers [1]. The present scheme should allow the realization of optical barriers for atoms on the scale of tens of nanometers, and in combination with traditional optical potentials and lattices the formation of a complex 'nanoscale' optical landscape for atoms. Our discussion should be of particular interest for realizing many-atom quantum dynamics as a strongly interacting many-body systems, where atomic energy scales and interactions, such as magnetic dipolar couplings, are strongly enhanced by subwavelength distances. We illustrate the concepts with a double layer potential for atoms obtained from inserting an optical subwavelength barrier into a well generated by an off-resonant optical lattice, and discuss bound states of pairs of atoms interacting via magnetic dipolar interactions. The subwavelength optical barriers represent an optical 'Kronig-Penney' potential. We present a detailed study of the bandstructure in optical 'Kronig-Penney' potentials, including decoherence from spontaneous emission and atom loss to open 'bright' channels.

[1] M. Lacki, M. Baranov, H. Pichler, P. Zoller, arXiv:1607.07338

Mon 28, 09:45 am

T2 – Circuit Quantum Electrodynamics with Silicon Quantum Dots

X. Mi[1], J. V. Cady[1], D. M. Zajac[1], P. W. Deelman[2], J. R. Petta[1]
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Isotopically enriched silicon has been termed a "semiconductor vacuum" due to its ability to support very long quantum coherence times. I will describe recent efforts by my group to couple a single electron trapped in a Si/SiGe double quantum dot to the photonic field of a superconducting coplanar waveguide resonator. A high degree of control over a single electron wavefunction is achieved using a recently developed overlapping aluminum gate electrode architecture. Measurements of the microwave transmission through the superconducting resonator allow sensitive measurements of the charge state occupation of the Si/SiGe double quantum dot. Charge-cavity coupling rates as large as 30 MHz are achieved and the cavity response is in excellent agreement with cavity input-output theory.

Monday morning session II

Chairperson: M. Kiselev

Mon 28, 11:00 am

T3 – A classical single ion heat engine and its extension to spin-driven quantum engines

J. Roßnagel, S. Dawkins, N. Tolazzi, O. Abah, E. Lutz, K. Singer, U. Poschinger,
D. von Lindenfels, F. Schmidt-Kaler
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Heat engines convert thermal energy into mechanical work and generally involve a large number of particles. We report the experimental realization of a single-atom heat engine. An ion is confined in a linear Paul trap with tapered geometry and driven thermally by coupling it alternately to hot and cold reservoirs. The output power of the engine is used to drive a harmonic oscillation. From direct measurements of the ion dynamics, we were able to determine the thermodynamic cycles for various temperature differences of the reservoirs. We then used these cycles to evaluate the power P and efficiency η [1]. Furthermore, we extend the conversion of thermal bath energies into coherent motion to the single ion operation close to the quantum mechanical ground state. Here, we employ spin-dependent optical light forces [2] to engineer a work engine cycle and demonstrate the operation in the quantum regime.

[1] Science 352, 325 (2016)

[2] Phys. Rev. Lett. 116, 033002 (2016)

Mon 28, 11:45 am

T4 – Ion chains in optical cavities

C. Cormick[1], T. Fogarty[2], G. Morigi[2]
[1] *Instituto de Física Enrique Gaviola, FAMAF, UNC and CONICET, Argentina.*
[2] *Saarland University, Germany.*

The dynamics of cold trapped ions in a high-finesse resonator results from the interplay between the long-range Coulomb repulsion and the cavity-induced interactions due to multiple photon scatterings. We study the stationary states of ions coupled with a mode of a standing-wave cavity in cases when the resonator-mediated interactions are specially relevant. The two examples we consider are the vicinity of a structural transition and of a sliding-pinned transition of the ion chain. We find that the cavity induces the existence of regions where two phases are stable, while the photons leaking out due to mirror losses provide a non-invasive means to monitor the dynamics. Moreover, we show that the optomechanical coupling can be used to cool the ion vibrations to the ground state in appropriate regimes.

Monday afternoon session I

Chairperson: C. A. Balseiro

Mon 28, 02:30 pm

T5 – Topological Physics in HgTe-based Quantum Devices

L.W. Molenkamp
University of Wuerzburg, Physics Institute, EP 3

Suitably structured HgTe is a topological insulator in both 2- (a quantum well wider than some 6.3 nm) and 3 (an epilayer grown under tensile strain) dimensions. The material has favorable properties for quantum transport studies, i.e. a good mobility and a complete absence of bulk carriers, which allowed us to demonstrate variety of novel transport effects. One aspect of these studies is topological superconductivity, which can be achieved by inducing superconductivity in the topological surface states of these materials. Special emphasis will be given to recent results on the ac Josephson effect. We will present data on Shapiro step behavior that is a very strong indication for the presence of a gapless Andreev mode in our Josephson junctions, both in 2- and in 3-dimensional structure. An additional and very direct evidence for the presence of a zero mode is our observation of Josephson radiation at an energy equal to half the superconducting gap. Controlling the strain of the HgTe layers strain opens up yet another line a research. We have recently optimized MBE growth of so-called virtual substrates ((Cd,Zn)Te superlattices as a buffer on a GaAs substrate), that allow us to vary the strain from 0.4% tensile to 1.5% compressive. While tensile strain turns 3-dimensional HgTe into a narrow gap insulator, compressive strain turns the material into a topological (Weyl) semimetal, exhibiting clear signs of the Adler-Bell-Jackiw anomaly in its magnetoresistance. In quantum wells, compressive strain allows inverted energy gaps up to 60 meV.

Mon 28, 03:15 pm

T6 – Universal chiral quasi-steady states in periodically driven many-body systems

N. H. Lindner[1], E. Berg[2], and M. S. Rudner[3]
[1] *Technion Institute of Technology, Haifa, Israel.*
[2] *Weizmann Institute of Science, Rehovot, Israel.*
[3] *University of Copenhagen, Copenhagen, Denmark.*

At very high driving frequencies, energy absorption in a periodically driven many-body system may be suppressed, opening an exponentially long time window in which the system ”prethermalizes” as if its dynamics were governed by an effective, local, time-independent Hamiltonian. Here we uncover a new regime of prethermalization, occurring for *low-frequency* driving in systems with multiple intrinsic energy scales (e.g., continuous bands separated by a large gap). In this case, the system rapidly absorbs energy from the driving field and heats the low-energy degrees of freedom to a restricted infinite-temperature-like state, which only gives way to full mixing with the high energy degrees of freedom on a timescale that is exponentially long in the inverse of the driving frequency. Such states offer a new paradigm of topological transport in non-equilibrium many-body systems: in the calculation of observables such as the Hall conductivity in 2D or the pumping current in 1D, the infinite temperature state restricted to low-energy bands yields uniform momentum space averages over the Berry curvature and Floquet-Bloch band group velocity, respectively, yielding universal results proportional to corresponding topological invariants. Here we focus on the case of a partially-filled (and therefore gapless) version f the Thouless pump in one dimension, and show that rapid heating indeed leads to a universal current-carrying quasi-steady state for low-frequency driving. In such a state, which can be realized for both bosons and fermions, the pumped charge per driving period is determined solely by the product of the particle density and the Floquet band quasienergy winding number. This novel type of prethermalized state is fundamentally unlike any equilibrium state and cannot be described in terms of any local, static, effective Hamiltonian. Recently developed cold atom systems offer a promising platform for investigating this new regime of driven many-body dynamics.

Monday afternoon session II

Chairperson: C. A. Balseiro

Mon 28, 04:30 pm

T7 – Time-Reversal Symmetry and Coherent Scattering in Driven Two-Level Systems

William D. Oliver
Engineering Quantum Systems (EQuS) Group, Massachusetts Institute of Technology

We present several examples of Landau-Zener-Stueckelberg-mediated quantum interference in a strongly-driven superconducting qubit, including interferometry [1], microwave cooling [2], and amplitude spectroscopy [3]. We use this system to emulate universal conductance fluctuations by implementing a biharmonic driving field capable of feature both symmetric and asymmetrical temporal scattering [4]. Time permitting, we present results from a recent high-coherence capacitively shunted flux qubit [5].

[1] W.D. Oliver et al., Science 310, 1653 (2005)

[2] S.O. Valenzuela et al., Science 314, 1589 (2006)

[3] D.M. Berns et al., Nature 455, 51 (2008)

[4] S. Gustavsson et al., PRL 110, 016603 (2013)

[5] F. Yan et al., Nature Communications 7, 12964 (2016)

Mon 28, 05:15 pm

T8 – Coexistence of dissipative and phase-coherent transport channels in a driven three-terminal Josephson junction.

D. Feinberg[1], R. Mélin[1], B. Douçot[2], C. Padurariu[3], T. Jonckheere[4]
[1] *Institut Néel, CNRS and Université Grenoble-Alpes, Grenoble, France.*
[2] *LPTHE, CNRS and Universités Paris 6 et 7, Paris, France.*
[3] *Department of Applied Physics, Aalto University, Aalto, Finland.*
[4] *CPT, CNRS and Aix-Marseille Université, Marseille, France.*

Three-terminal Josephson junctions biased at commensurate voltages display the coexistence of different transport channels. Besides the multiple Andreev reflections carrying quasiparticles, new phase-coherent modes appear, made of energy-conserving motion of clusters of Cooper pairs (minimally two, as an electronic quartet) involving all three terminals. These features which do not exist in a simple Josephson junction can be understood in terms of dynamical Andreev resonances and lead to a variety of phenomena such as $0-\Pi$ transitions and crossed quantum noise. Recent experiments in metallic and nanowire junctions confirm this picture.

Tuesday morning session I

Chairperson: Y. Gefen

Tue 29, 09:00 am

T9 – Quantum Ising machines with parametrically modulated nonlinear oscillators

Shruti Puri[1], Christian Kraglund Andersen[1], Arne L. Grimsmo[1] and Alexandre Blais[1,3]
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[2] *Department of Physics and Astronomy, Aarhus University, DK-8000 Aarhus, Denmark*
[3] *Canadian Institute for Advanced Research, Toronto, Canada*

Quantum annealing exploits quantum fluctuations to solve combinatorial optimization problems that can be encoded into the couplings of Ising Hamiltonians. In this talk, I will introduce a new paradigm for quantum annealing that relies on continuous variable states. In this approach, quantum information is encoded in two coherent states of the field that are stabilized by two-photon driving in a nonlinear resonator. To motivate the underlying physics, I will first present an approach to prepare high-fidelity cat states in this system. I will then outline an adiabatic annealing protocol in an all-to-all connected network of nonlinear resonators. Numerical simulations indicate substantial resilience to photon loss in this system. Finally, I will discuss realizations of these ideas in superconducting circuits.

Tue 29, 09:45 am

T10 – Comparing Experiments to the Fault-Tolerance Threshold

Andrew C. Doherty
Centre for Engineered Quantum Systems, School of Physics, University of Sydney, Sydney, NSW, Australia

The fault-tolerance threshold theorem is a fundamental result that justifies the tremendous interest in building large-scale quantum computers despite the formidable practical difficulties imposed by noise and imperfections. This theorem gives a theoretical guarantee that quantum computers can be built in principle if the noise strength and correlation are sufficiently low. To make precise statements of threshold theorems, we must quantify the strength of errors in noisy quantum operations. Ideally we would do this in terms of quantities that can be measured in experiments. A standard measure for quantifying errors in quantum gates is the average error rate. This quantity has many virtues: it can be estimated efficiently in experiments, and in a manner that is independent of state preparation and measurement (SPAM) errors by using the now standard method of randomized benchmarking. The major drawback of using average error rate to quantify gate errors is that it is only a proxy for the actual quantity of interest, the fault-tolerance threshold. This is because average error rate captures average-case behavior for a single use of the gate, while fault tolerance theorems characterize noise in terms of worst-case performance when the gate is used repeatedly in a large computation. This work investigates the relationship between worst-case and average-case error for a wide range of error models that are relevant to experiments. We show that well-established theoretical techniques of convex optimization are often sufficient to determine the relationship between average-case and worst-case errors for models of physical interest. Secondly, we study a wide range of error models for one-qubit gates. Our main example is of a one-qubit gate with combined dephasing and calibration error. This allows us to demonstrate the crossover between a regime dominated by dephasing, where average-case and worst-case errors are not too different, and the limit of unitary noise, where they can be very different. We show that for all unitary errors there is a large difference between average case and worst case errors. While this motivates new investigations into the possibilities for benchmarking experiments to bound worst-case errors, it also suggests that more work should be done to understand the performance of current approaches to fault tolerant quantum computing in the presence of unitary errors. I will describe initial results on the performance of standard error correction protocols in the presence of unitary errors. Work in collaboration with Richard Kueng, David Long, Eric Huang and Steven Flammia.

Tuesday morning session II

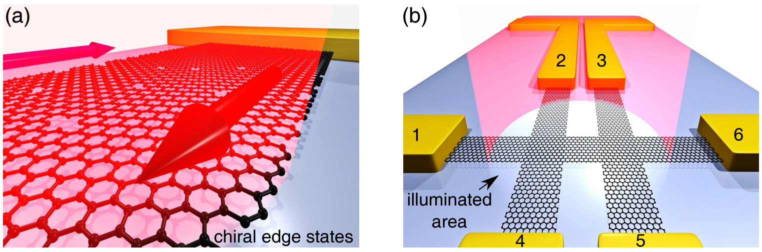
Chairperson: Y. Gefen

Tue 29, 11:00 am

T11 – Using light as a topological switch: The roads towards Floquet topological insulators

L. E. F. Foa Torres[1]
[1] *Departamento de Física, FCFM, Universidad de Chile*

Light-matter interaction is at the heart of intriguing phenomena and has led to many practical applications like, for instance, Raman spectroscopy. But beyond characterization, several studies have gone deeper into actually using light to modify the electrical properties of a material. This can be done, for example, by using light to switch off the conduction in graphene [1,2] (or other materials [3]), thereby allowing to tune the material's response with optical means, or even inducing tunable topological states in materials that would otherwise lack them [1,2,4,5,6,7,8] (i.e. a Floquet topological insulator [4]). The latter would expand the playground of topological insulators to a broader set of materials. Recently, laser-induced bandgaps have been experimentally verified at the surface of a topological insulator [3] adding much interest to this area. In this talk I will provide an overview of our recent works in this field with a focus on the generation of Floquet chiral edge states in graphene [6,9,10] (Fig. 1(a)), and other materials including topological insulators [8,11]. The emergence of a Hall response without Landau levels [12] (see scheme in Fig. 1(b)) and open problems will also be highlighted.



The scheme in (a) represents the chiral edge states predicted in illuminated graphene [6,9]. These chiral edge states lead, in a multiterminal setup as shown in panel (b), to a Hall response [12].

[1] T. Oka and H. Aoki, Phys. Rev. B **79**, 081406 (2009).

[2] H. L. Calvo, H. M. Pastawski, S. Roche, and L. E. F. Foa Torres, Appl. Phys. Lett. **98**, 232103 (2011); H. L. Calvo, P. M. Perez-Piskunow, S. Roche, and L. E. F. Foa Torres, Appl. Phys. Lett. **101**, 253506 (2012).

[3] Y. H. Wang, H. Steinberg, P. Jarillo-Herrero, and N. Gedik, Science **342**, 453 (2013).

[4] N. H. Lindner, G. Refael, and V. Galitski, Nat. Phys. **7**, 490 (2011).

[5] T. Kitagawa, T. Oka, A. Brataas, L. Fu, and E. Demler, Phys. Rev. B **84**, 235108 (2011).

[6] P. M. Perez-Piskunow, G. Usaj, C. A. Balseiro, and L. E. F. Foa Torres, Phys. Rev. B **89**, 121401(R) (2014).

[7] E. Suárez Morell and L. E. F. Foa Torres Phys. Rev. B **86**, 125449 (2012).

[8] H. L. Calvo, L. E. F. Foa Torres, P. M. Perez-Piskunow, C. A. Balseiro and G. Usaj, Phys. Rev. B **91**, 241404(R) (2015).

[9] G. Usaj, P. M. Perez-Piskunow, L. E. F. Foa Torres, and C. A. Balseiro Phys. Rev. B **90**, 115423 (2014); P. M. Perez-Piskunow, L. E. F. Foa Torres and G. Usaj, Phys. Rev. A **91**, 043625 (2015).

[10] D. A. Lovey, G. Usaj, L. E. F. Foa Torres, C. A. Balseiro, Phys. Rev. B **93**, 245434 (2016).

[11] V. Dal Lago, M. Atala and L. E. F. Foa Torres, Phys. Rev. A **92**, 023624 (2015).

[12] L. E. F. Foa Torres, P. M. Perez-Piskunow, C. A. Balseiro, and G. Usaj, Phys. Rev. Lett. **113**, 266801 (2014).

Tue 29, 11:45 am

T12 – Spin dynamics in graphene

Sergio O. Valenzuela[1,2]
[1] *Catalan Institute of Nanoscience and Nanotechnology (ICN2), CSIC and The Barcelona Institute of Science and Technology,Campus UAB, Bellaterra, 08193 Barcelona, Spain*
[2] *Institució Catalana de Recerca i Estudis Avançats (ICREA), 08070 Barcelona, Spain*

Graphene is considered an excellent candidate for spin qubits and spintronics in general. This is because spin orbit coupling in carbon is weak, owing to the low atomic weight, and because hyperfine interaction is absent with the predominant zero-spin isotope 12C. Indeed, it is not surprising that initial predictions of the spin lifetime at room temperature for pristine graphene fell in the microsecond range. In contrast to these expectations, spin transport experiments have demonstrated spin lifetimes that are typically below 10 ns and, despite increasing research efforts, the microscopic process driving such a fast spin relaxation remains unknown. In this talk, I will first describe the two main candidate mechanisms that are currently being considered to explain these observations. They are unique to graphene and involve either resonant scattering with magnetic centers [1] or spin-pseudospin coupling and Rashba spin-orbit interaction [2]. Regardless of the differences in the microscopic processes, I will show that both of these models are able to explain all of the key features of classical spin transport experiments. I will then discuss recent experimental efforts aiming at highlighting their peculiarities; in particular, at verifying whether the spin relaxation is anisotropic, which would be the hallmark of the presence of a dominant spin orbit field [3] that could be associated with spin Hall effects [4]. I will also discuss the need of identifying spin relaxation channels in the presence of contacting electrodes and their variability due to inhomogeneous carrier distributions [5]. Understanding these phenomena is crucial to increase the spin lifetime towards the theoretical limit, to find ways of controlling the spin lifetime, and to ultimately develop novel approaches for spin-based information processing protocols relying on graphene.

[1] D. Kochan, M. Gmitra, and J. Fabian, Phys. Rev. Lett. 112, 116602 (2014).

[2] D. Van Tuan, F. Ortmann, D. Soriano, S. O. Valenzuela, and S. Roche, Nature Phys. 10, 857863 (2014).

[3] B. Raes, J. E. Scheerder, M. V. Costache, F. Bonell, J. F. Sierra, J. Cuppens, J. Van de Vondel and S. O. Valenzuela, Nature Commun. 7, 11444 (2016).

[4] J. Sinova, S. O. Valenzuela, J. Wunderlich, C. H. Back, and T. Jungwirth, Rev. Mod. Phys. 87, 1213 (2015); D. Van Tuan, J. M. Marmolejo-Tejada, X. Waintal, B. K. Nikolíc, S.O. Valenzuela, and S. Roche Phys. Rev. Lett. (in press).

[5] J. Cuppens, S. O. Valenzuela, et al., unpublished.

Tuesday afternoon session I

Chairperson: H. M. Pastawski

Tue 29, 02:30 pm

T13 – Directly driving donor nuclear spins in silicon with an electric field

A. Sigillito, A. Tyryshkin, and S.A. Lyon
Department of Electrical Engineering, Princeton University, Princeton, NJ, 08544, USA

Usually one needs to apply an RF magnetic field to drive nuclear spin transitions. Surprisingly however, recent data shows that the nuclear spins of both phosphorus and arsenic donors in Si can be driven by an RF electric field. These data have been obtained using superconducting coplanar microwave resonators consisting of photonic bandgap mirrors at either end of a half-wavelength section of transmission line. This structure allows us drive the nuclear spins at frequencies below the resonance with a current through the center pin of the coplanar structure, or just a voltage if the center pin is disconnected at one end. The nuclear transition is detected through the donor's electron spin using the microwave resonator and pulsed electron-nuclear double resonance (pulsed ENDOR). The phosphorus donor nuclear spin is 1/2, which eliminates explanations of the electric field driving based on a nuclear quadrupole moment. Instead we will suggest an explanation based upon the Stark shift of the electron spin resonance. This explanation is supported by the observation of the nuclear spins being driven at a subharmonic of the NMR frequency.

Tue 29, 03:15 pm

T14 – Charge and energy transport in driven quantum electron systems

Liliana Arrachea
International Center for Advanced Studies, Universidad Nacional de San Martín

I will present an adiabatic response formalism and a generalization of the thermoelectric theory to describe the exchange of heat, work and charge in electron systems under the effect of adiabatic ac driving, in addition to voltage and temperature biases. Different operational modes will be identified: motors, generators, heat engines and heat pumps, which will be characterized in terms of efficiencies and figures of merit. Some examples will be discussed. Finally, the adiabatic response formalism will be also used to investigate the non-linear dynamics of the charge and energy in a quantum capacitor.

Tuesday afternoon session II

Chairperson: H. M. Pastawski

Tue 29, 04:30 pm

T15 – Engineered Fractional Quantum Hall State through Dissipation

Raul A. Santos[1], Alexander Altland[2], Alex Kamenev[3], Yuval Gefen[1]
[1] *Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot, 76100 Israel.*
[2] *Institut für Theoretische Physik, Universität zu Köln, Zülpicher Str. 77, D-50937 Köln, Germany*
[3] *William I. Fine Theoretical Physics Institute, University of Minnesota, Minneapolis, MN 55455, USA*

Topological states of fermionic matter can be found in nature, or engineered in various ways. Here we employ dissipative dynamics, along with a driving laser source, to create a Fractional Quantum Hall ground state on a torus. The interplay of steady state driving and dissipative cooling is harnessed to purify the targeted state. We first employ a unitary map from the two-dimensional setup onto a one-dimensional problem of fermions hopping in pairs, conserving their center of mass momentum. We show how the two-dimensional Laughlin state (expressed through this unitary mapping) can be obtained as the dark state of a quantum master equation, obtained through the dissipative dynamics.

[1] R.A.Santos, A. Altalnd, A. Kamenev, Y. Gefen, to be published.

Tue 29, 05:15 pm

T16 – Role of inelasticity in the symmetry of the Onsager matrix

Guillem Rosselló[1], Rosa López[1], Rafael Sánchez[2]
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[2] *Instituto Gregorio Millán, Universidad Carlos III de Madrid*

The role of energy exchange between a quantum system and its environment is investigated from the perspective of the Onsager conductance matrix. We consider the thermoelectric linear transport of an interacting quantum dot coupled to two terminals under the influence of an electrical potential and a thermal bias. We implement in our model the effect of coupling to electromagnetic environmental modes created by nearby electrons within the P(E)-theory. Our findings relate the lack of some symmetries among the Onsager matrix coefficients with an enhancement of the efficiency at maximum power and the occurrence of the heat rectification phenomenon.

Wednesday morning session I

Chairperson: L. Arrachea

Wed 30, 09:00 am

T17 – Dissipative Phase Transitions

Rosario Fazio
ICTP, Strada Costiera 11, 34151 Trieste, Italy

Thanks to the recent impressing experimental progresses, the investigation of non-equilibrium properties of driven-dissipative systems in quantum systems has received an impressive boost. Rydberg atoms in optical lattices, systems of trapped ions, excitonpolariton condensates, cold atoms in cavities, arrays of coupled QED cavities, are probably the most intensively investigated experimental platforms in relation to this aim. The predicted steady-state phase diagram of these driven dissipative systems becomes incredibly rich, displaying a variety of phenomena. In my presentation I will discuss several aspects that are peculiar of these systems, not shared with the conventional picture we have at equilibrium. I will discuss in particular the possible existence of exotic phases in the steady state and the unusual role of short-range fluctuations played to determine the phase diagram.

Wed 30, 09:45 am

T18 – Decoherence of quantum two-level system by spectral diffusion

S. Matityahu[1], A. Shnirman[2], G. Schön[3,4] and M. Schechter[1]
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[2] *Institut für Theorie der Kondensierten Materie, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany.*
[3] *Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany.*
[4] *Institute of Nanotechnology, Karlsruhe Institute of Technology, D-76344 Eggenstein-Leopoldshafen, Germany*

Recent progress with microfabricated quantum devices has revealed that an ubiquitous source of noise originates from parasitic two-level systems (TLSs). For superconducting qubits, TLSs residing on surfaces or in tunnel junctions account for a major part of dephasing and thus pose a serious roadblock to the realization of solid-state quantum processors. Recent experiments of Lisenfeld et al. demonstrated that it is possible to utilize a superconducting qubit to explore the quantum state evolution of such high-frequency TLSs. We found that a major source of dephasing of the probed high-frequency TLSs is their interaction with thermal, low-frequency TLSs. The so-called standard model of TLS is sufficient to quantitatively explain the Ramsey-type experiments. The effect of low-frequency TLSs is efficiently reduced by spin-echo techniques. The remaining dephasing observed in the echo protocol is due to further noise sources with a more white spectrum.

Wednesday morning session II

Chairperson: L. Arrachea

Wed 30, 11:00 am

T19 – Quantum Dynamical Phase Transitions of Non-Hermitian Hamiltonians and Lindblad dynamics: their key role in quantum information, chemistry and electronics

H. M. Pastawski
FaMAF and Instituto de Física Enrique Gaviola (CONICET-Universidad Nacional de Córdoba)

Exceptional points or spectral bifurcations appeared when we experimentally observed a Quantum Dynamical Phase Transition for a spin dimmer in the presence of a non-quiral spin environment [1]. In this case the effective Hamiltonian results non-Hermitian, a realistic situation that quite convenient to taylor the creation and propagation of plasmonics excitation in waveguides [2]. This also resulted crucia crucial to explain molecular dissociation/formation in presence of a catalyst (M). We considered two paradigmatic cases: a molecule with its axis perpendicular to the surface (e.g. Heyrovsky reaction of H2) [3]. We further observed that spectral bifurcations (exceptional points) may appear in strictly positive dynamics, i.e. solutions of the Keldysh or Lindblad equations. [4], even when the exceptional points are not present at the non-Hermitian Hamiltonian level [5] An example of this dynamics in a double quantum dot and other SWAP gates. I also will explore how QDPT manifests in a definite positive evolution. I introduce our new numerical algorithm, the quantum drift (QD), a dynamical implementation of the D'Amato-Pastawski model that simplifies the Keldysh quantum fields formalism[4]. We show that QD dynamics easily captures QDPT. As QD involves a single pure wave function that represents the whole thermal ensemble, it is very effective to push the computational limits for decoherent many-body dynamics.[6] Furthermore, by implementing a forward quantum dynamics followed by another one backwards in time and evaluating the Loschmidt Echo, we find that decoherence does not occur uniformly in time but that it is more effective while the state goes through a superposition (entangled) state. This is consistent with our recent experimental findings [7] that the non-local entangled state are more sensitive to the action of local environments than the simple pointer states where the action of the environment is reduced to a change in the global phase.

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[2] RA Bustos-Marún, EA Coronado, and HMP, J. Phys.Chem. C, 116, 18937 (2012); RA Bustos-Marún, AD Dente, EA Coronado,HMP, Plasmonics 9, 925 (2014)

[3] A Ruderman, AD Dente, E Santos and HMP, JPCM, 27 315501 (2015); Mater.Res.Express 3 085017(2016)

[4] HMP, Phys. B 398, 278(2007).

[5] EP Danieli, GA Álvarez, PR Levstein and HM Pastawski, Sol.St.Comm. 141, 422 (2007)

[6] LJ Fernández-Alcázar and HMP, Phys.Rev. A 91, 022117 (2015)

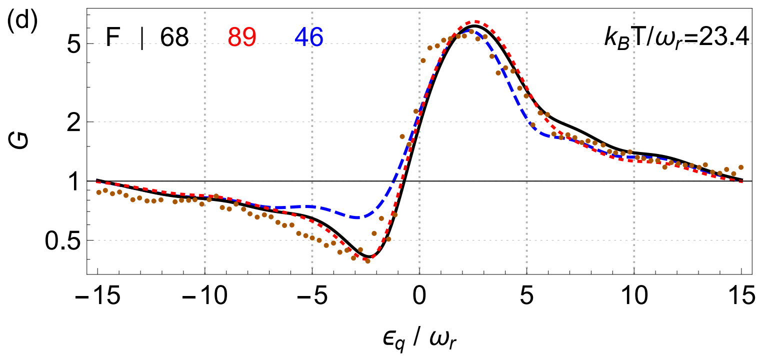
[7] CM Sánchez, PR Levstein, L Buljubasich, HMP, AK. Chattah, Phil.Trans.R.Soc. A 374 20150155(2016)

Wed 30, 11:45 am

T20 – Synthesising Keldysh and Lindblad - Correlated decay processes in higher order perturbation theory

C. Mueller, T. S. Stace
ARC Centre of Excellence for Engineered Quantum Systems, The University of Queensland, Brisbane, Australia

Motivated by correlated decay processes driving gain, loss and lasing in driven semiconductor quantum-dots [1-3], we develop a theoretical technique using Keldysh real time diagrammatic perturbation theory to derive a Lindblad master equation that goes beyond the usual second order perturbation theory. We demonstrate the method on the driven dissipative Rabi model, including terms up to fourth order in the interaction between the qubit and both the resonator and environment. This results in a large class of Lindblad dissipators and associated rates which go beyond the terms that have previously been proposed to describe similar systems [4]. All of the additional terms terms contribute to the system behaviour at the same order of perturbation theory, and make substantial contributions to the behaviour of the system. We then apply these results to analyse the phonon-assisted steady-state gain of a microwave field driving a double quantum-dot in a resonator. We show that resonator gain and loss are substantially affected by dephasing-assisted dissipative processes in the quantum-dot system [5]. These additional processes, which go beyond recently proposed polaronic theories, are in good quantitative agreement with experimental observations



Microwave power gain, G, versus DQD bias, ϵ_q. Points are experimental data extracted from [1]. The blue-dashed theory curve is generated using only terms corresponding to the polaron transformation used in [3]. The solid-black theory curve is generated using the dominant terms in the full master equation [5]. The dotted red curve includes all additional dissipators discussed in [4].

[1] Liu et al., Phys. Rev. Lett. 113, 036801 (2014)

[2] Liu et al., Science 347, pp.285-287 (2015)

[3] Gullans et al., Phys. Rev. Lett. 114, 196802 (2015)

[4] C. Mueller, and T. S. Stace, arXiv:1608.04163 (2016)

[5] C. Mueller, and T. S. Stace, arXiv:1608.04164 (2016)

Thursday morning session I

Chairperson: D. Feinberg

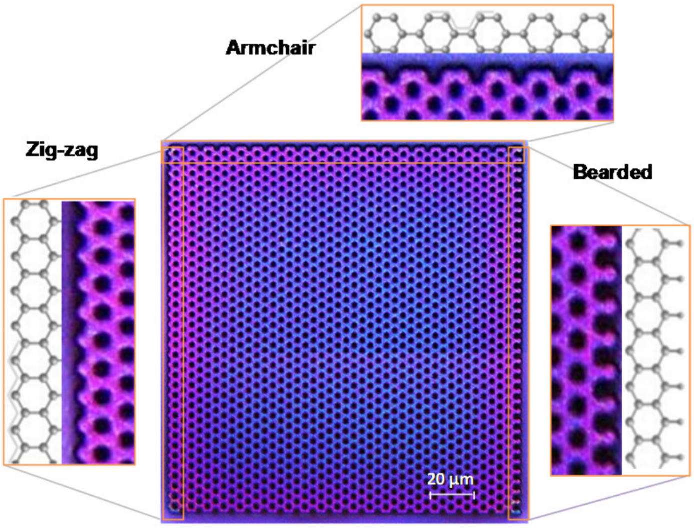
Thu 1, 09:00 am

T21 – Edge states in a polariton honeycomb lattice

M. Milicevic[1], T. Ozawa[2], G. Montambaux[3], I. Carusotto[2], A. Lemaitre[1], L. Le Gratiet[1], I. Sagnes[1], J. Bloch[1], A. Amo[1]

[1] *Centre de Nanosciences et de Nanotechnologies, CNRS, Univ. Paris-Sud, Université Paris-Saclay, C2N-Marcoussis, 91460 Marcoussis, France.* [2] *INO-CNR BEC Center and Dipartimento di Fisica, Università di Trento, I-38123, Povo, Italy.* [3] *Laboratoire de Physique de Solids- CNRS UMR 8502, Univeristé Paris-Sud F-91405 Orsay Cedex, France.*

The experimental study of edge states in atomically-thin layered materials like graphene or TMDs remains a challenge due to the difficult control on the geometry of the sample terminations, the stability of dangling bonds and the need to measure local properties. Photonic microstructures present an extraordinary workbench to emulate and study the transport properties and the connection to topology of the edge states of this kind of structures. Here we report on the observation of edge states in a honeycomb lattice of coupled micropillars [1]. The lowest two polaritonic bands of this structure arise from the coupling of the lowest energy modes of each micropillar, and emulate the π and π^* bands of graphene holding unidimensional quasi-flat edge states [2]. Most interestingly the first excited states of each micropillar resonator have a P-orbital geometry giving rise to bands containing novel dispersive edge states with an orbital structure [3]. Our system presents interesting perspectives in view of studying nonlinear edge modes taking advantage of the significant polariton-polariton interactions and shows the feasibility of studying topological edge state physics in a photonic environment [4, 5].



Optical microscope image of a polariton honeycomb lattice containing zig-zag, bearded and armchair edges.

[1] T. Jacqmin et al., Phys. Rev. Lett. 112, 116402 (2014)

[2] M. Milicevic et al., 2D Mater. 2, 34012 (2015)

[3] M. Milicevic et al., arxiv: 1609.06485

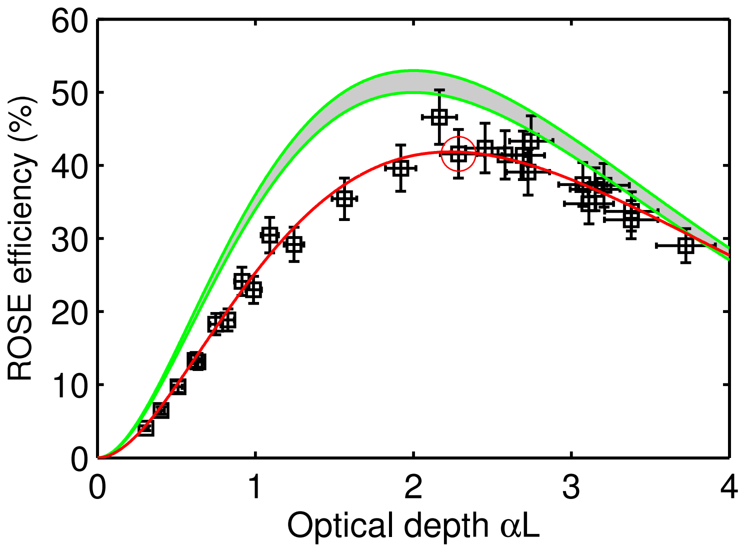
[4] A. V. Nalitov et al., Phys. Rev. Lett. 114, 116401 (2015)

Thu 1, 09:45 am

T22 – Erbium doped materials for optical quantum memories

J. Dajczgewand[1], R. Ahlefeldt[1], A. Louchet-Chauvet[1], J.-L. Le Gouët[1], T. Chanelière[1]
[1] *Laboratoire Aimé Cotton, UMR 9188, CNRS, Université Paris-Sud, ENS Cachan, Université Paris-Saclay, Bâtiment 505, Campus Universitaire, 91405 Orsay, France*

Rare-earth doped solids are known for their luminescence properties. Among them erbium takes a special place because the Erbium Doped Fiber Amplifier has revolutionized the telecommunications by giving access to long distance communication. The transposition of this scheme to quantum cryptography is appealing. The core element of the so-called quantum repeater is an optical memory [1]. Even if the compatibility with the telecom bands can be ensured by non-linear frequency conversion, a direct operation at 1.5μm is desirable. This is the approach we take by using an erbium doped crystal which falls directly in the C-band of telecom. I'll essentially review the recent work that we did on an erbium doped yttrium orthosilicate sample (Er^{3+}:Y_2SiO_5) by applying an original protocol named Revival of Silenced Echo (ROSE) [2]. The ROSE is quite efficient in Er^{3+}:Y_2SiO_5 [3] as compared to other protocols. The main advantage is the potentially large bandwidth and the high frequency multiplexing capacity. I'll finally show that these performances are limited by the erbium-erbium electron spin interaction [4]. Although we work on the optical transition, the spin properties are absolutely critical for the coherence time governing the memory storage time. As an illustration, I'll present a recent study of an Er^{3+}:Y_2SiO_5 crystal in which we added a controlled level of disorder with scandium as co-dopant [5]. This perturbation can surprisingly increase the coherence time at low magnetic field. This counter intuitive result is due to the reduction of Er-Er spin flip-flop rate because the disorder effectively slows down the flip-flop mechanism by making the magnetic interaction non resonant.



ROSE efficiency as a function of the optical depth αL from [3].

[1] F. Bussières , N. Sangouard , M. Afzelius , H. de Riedmatten , C. Simon , W. Tittel, J. Mod. Optics, Vol. 60, Iss. 18, (2013). K. Heshami and D. G. England and P. C. Humphreys and P. J. Bustard and V. M. Acosta and J. Nunn and B. J. Sussman, J. Mod. Optics, 63, 20, 2005-2028, (2016).

[2] V. Damon, M. Bonarota, A. Louchet-Chauvet, T. Chanelière, J.-L. Le Gouët, New J. Phys. 13:093031, (2011).

[3] J. Dajczgewand, J.-L. Le Gouët, A. Louchet-Chauvet, and T. Chanelière, Optics Letters, Vol. 39, 2711 (2014).

[4] J. Dajczgewand, R. Ahlefeldt, T. Böttger, A. Louchet-Chauvet, J.-L.Le Gouet, T. Chanelière, New J. Phys 17, 023031 (2015)

[5] S. Welinski, C. W. Thiel, J. Dajczgewand, A. Ferrier, R. L. Cone, R. M. Macfarlane, T. Chanelière, A. Louchet-Chauvet, and Ph. Goldner, Optical Materials, online Sept. 2016.

Thursday morning session II

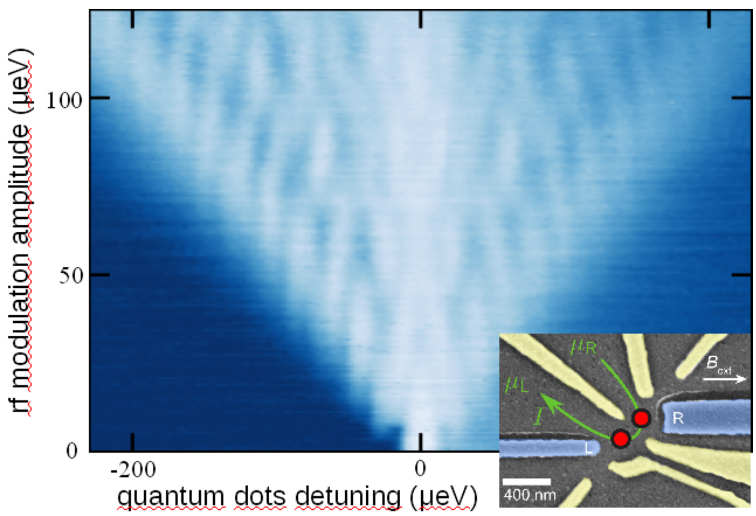
Chairperson: D. Feinberg

Thu 1, 11:00 am

T23 – Landau-Zener dynamics in a double dot charge qubit: probing coherence, environment & symmetries

F. Forster[1], S. Kohler[2], W. Wegscheider[3], S. Ludwig[1,4]
[1] *Center for NanoScience and University of Munich, Germany*
[2] *Instituto de Ciencia de Materiales de Madrid, Spain*
[3] *ETH Zürich, Switzerland*
[4] *Paul-Drude-Institute für Festkörperphysik, Berlin*

Landau-Zener transitions through avoided crossings allow the definition of superposition states and the precise control of qubits, an interesting alternative to commonly used non-adiabatic pulses. Repeated passages through an avoided crossing result in interference of the superposition state and give rise to Landau-Zener-Stückelberg-Majorana (LZSM) interference. In a first experiment we demonstrate the capabilities of LZSM interference as a tool to fully characterize a double quantum dot charge qubit including its dephasing environment. Applying a Floquet theory based complete transport model we are able to extract the qubits coherence time from steady state transport measurements. The coherence is limited even at very low temperatures by the electron-phonon interaction while environmental charge noise causes a strong inhomogeneous dephasing of the steady state (ensemble) measurement. At 20 mK our charge qubit has a coherence time of 200 ns. In a second experiment we explore the qubits dynamics under non-monochromatic periodic or quasi-periodic driving (through the avoided crossing). For bichromatic driving the symmetry properties of the interference pattern depend fundamentally on the commensurability properties of the driving force. Non-monochromatic driving promises new possibilities for information processing or quantum simulation experiments.



Landau-Zener-Stückelberg-Majorana interference pattern in the tunneling current through a double quantum dot for quasi-periodic bichromatic driving with incommensurate frequencies. The inset presents a scanning electron microscope image of the gate structure on the GaAs/AlGaAs heterostructure surface defining the device.

Thu 1, 11:45 am

T24 – Landau - Zener interferometry in multilevel systems

Mikhail N. Kiselev
ICTP, Strada Costiera 11, I-34151 Trieste, Italy

We propose a universal approach to the Landau-Zener (LZ) problem in a multilevel system. The problem is formulated in terms of generators of SU(N) algebra and maps the Hamiltonian onto the effective anisotropic pseudospin (N-1)/2 model. The vector Bloch equation for the density matrix describing the temporal evolution of the multilevel crossing problem is derived and solved analytically for two generic cases: i) three-level crossing problem representing a minimal model for a LZ interferometer and ii) four-level crossing problem corresponding to a minimal model of coupled interferometers. It is shown that the analytic solution of the Bloch equation is in excellent quantitative agreement with the numerical solution of the Schroedinger equation for the 3- and 4-level crossing problems. The solution demonstrates oscillation patterns which radically differ from the standard patterns for the two-level Landau- Zener problem: "beats" when the dwell time in the interferometer is smaller compared to a tunnel time and "steps" in the opposite limit. The possibilities of the experimental realization of LZ interferometers in the system of coupled quantum dots, Josephson charge qubits and in two-well traps for cold gases are discussed.

Thursday afternoon session I

Chairperson: T. Chanelière

Thu 1, 02:30 pm

T25 – Driven Transport in Quantum Dots: Biharmonic Excitations and Topological Effects

S. Kohler
Instituto de Ciencia de Materiales de Madrid, CSIC, 28049 Madrid, Spain

When an energy level of a quantum dot is swept such that it crosses a level of the other dot, one observes Landau-Zener transitions. Repeated sweeps lead to the so-called Landau-Zener-Stückelberg-Majorana interference visible in a characteristic pattern of the current as a function of the detuning and the amplitude of the sweeps. When driving the system with two ac fields, the symmetry of the interference pattern reflects the commensurability of the driving frequencies. In particular, for commensurable frequencies, the symmetry depends on the relative phase between the two components, while in the incommensurable case, one finds a higher symmetry which otherwise is only found for certain phases. These predictions are confirmed by measurements [1]. At present, we witness an experimental trend towards longer arrays of quantum dots (possibly realized with conducting molecules) with tunable tunnel couplings. Choosing alternating values yields an implementation of the Su-Schrieffer-Heeger model, one of the simplest models with non-trivial topology. The presence of electron source and drain, allows one to investigate the impact of topological effects on the current. It turns out that its shot noise is particularly affected by the corresponding edge states [2]. When the array is driven by an ac field, one may suppress tunneling and, thus, the current. Here we find that the shape of the current suppressions depends on topology [3].

[1] F. Forster, M. Mühlbacher, R. Blattmann, D. Schuh, W. Wegscheider, S. Ludwig, and S. Kohler, Landau-Zener interference at bichromatic driving, Phys. Rev. B 92, 245422 (2015).

[2] M. Benito, M. Niklas, G. Platero, and S. Kohler, Edge-state blockade of transport in quantum dot arrays, Phys. Rev. B 93, 115432 (2016).

[3] Transport, shot noise, and topology in ac-driven dimer arrays, M. Niklas, M. Benito, S. Kohler, and G. Platero, Nanotechnology 27, 454002 (2016).

Thu 1, 03:15 pm

T26 – Phase coherence and pairing amplitude in photo-excited superconductors

Luca Perfetti[1]
[1] *Laboratoire des Solides Irradiés, Ecole Polytechnique, 91128 Palaiseau, France*

New data on Bi2Sr2CaCu2O8-x reveal interesting aspects of photoexcited superconductors. The electrons dynamics show that inelastic scattering by nodal quasiparticles decreases when the temperature is lowered below the critical value of the superconducting phase transition. This drop of electronic dissipation is astonishingly robust and survives to photoexcitation densities much larger than the value sustained by long-range superconductivity. The unconventional behavior of quasiparticle scattering is ascribed to superconducting correlations extending on a length scale comparable to the inelastic mean-free path. Our measurements indicate that strongly driven superconductors enter in a regime without phase coherence but finite pairing amplitude. The latter vanishes near to the critical temperature and has no evident link with the pseudogap observed by Angle Resolved Photoelectron Spectroscopy.

Thursday afternoon session II

Chairperson: T. Chanelière

Thu 1, 04:30 pm

T27 – Nonlinear optics and light storage in cold atoms

J. W. R. Tabosa
Departamento de Física, Universidade Federal de Pernambuco, Cidade Universitária, 50670-901 Recife, PE, Brasil.

I will present an overview on different nonlinear optical phenomena in coherently driven cold atomic systems and discuss their applications for the reversible storage of light. Some atomic memories based on the phenomena of electromagnetically induced transparency (EIT), coherent population oscillation (CPO) and recoil-induced resonance (RIR) will be described. In particular, I will specially consider the case where the interacting light fields carry orbital angular momentum (OAM). The possibility of employing nonlinear higher order processes to the generation of multiphoton quantum correlation will also be discussed.

Thu 1, 05:15 pm

T28 – Quantum-classical analogies in photonic lattices: Fourier transforms

H. M. Moya-Cessa
Instituto Nacional de Astrofísica, Óptica y Electrónica, Puebla, Mexico

Optical analogies of quantum mechanical systems may help in the design of integrated optical structures [1]. This may be achieved because one can describe discrete systems, such as waveguide arrays in terms of Schrödinger-like equations by taking advantage that by choosing properly the (evanescent) interaction coefficients between the different waveguides, we may engineer particular setups that have a quantum counterpart. In the talk I will present some examples that model Fourier transforms [2,3].

[1] A. Perez-Leija, R. Keil, A. Szameit, A.F. Abouraddy, H. Moya-Cessa and D.N. Christodoulides, "Tailoring the correlation and anticorrelation behavior of path-entangled photons in Glauber-Fock oscillator lattices." Phys. Rev. A 85, 013848 (2012).

[2] S. Weimann, A. Perez-Leija, M. Lebugle, R. Keil, M. Tichy, M. Gräfe, R. Heilmann, S. Nolte, H. Moya-Cessa, G. Weihs, D. Christodoulides, A. Szameit, "Implementation of Quantum and Classical Discrete Fractional Fourier Transforms." Nature Communications 7, 11027 (2016).

[3] A. Perez-Leija, L.A. Andrade Morales, F. Soto-Eguibar, A. Szameit, and H. Moya-Cessa, "The Pegg-Barnett phase operator and the discrete Fourier transform." Phys. Scr. 91, 043008 (2016).

Thu 1, 05:45 pm

T29 – Quantum Simulations: Localization-delocalization transition in the dynamics of large quantum systems

Gonzalo A. Alvarez
Centro Atómico Bariloche, CNEA, CONICET, Bariloche, Argentina

Observing and controlling quantum systems like photons, electrons or nuclei can be used for storing and manipulating information in emerging technologies. These quantum technologies include a new kind of computers, the so-called quantum computers, which will be qualitatively faster than the most powerful computers currently available. These new types of computers allow the simulation of complex systems consisting of many components, like biological systems or other quantum systems. An outstanding challenge that needs to be overcome for developing these technologies is that one needs to control many interacting quantum systems. Quantum effects are extremely sensitive to external perturbations, which cause their quantum features to disappear extremely rapidly, and this problem grows quickly with increasing system size. I will report that the controlled creation of quantum states can show a novel type of phase transition on the coherent dynamic behavior of the quantum system [1]. Using nuclear magnetic resonance (NMR) on a solid-state system of spins at room-temperature, we suddenly turn on (quench) an interaction between the nuclear spins that starts to correlate them [2,3]. As a result, the collective system is driven into a quantum superposition. As time evolves, the number of correlated spins increases and consequently the extent of the coherent quantum state grows in space. We discovered that depending of the strength of a controlled external perturbation, the spreading in the space of the quantum correlations undergoes a transition from a delocalized "diffusion" to a localized one. These results show that in order to controllably create large quantum states, one needs to reduce the strength of any perturbation below a given threshold. Only below this threshold is the observed quantum system free to expand in space.

[1] G. A. Alvarez, D. Suter, and R. Kaiser. Science 349, 846 (2015).

[2] G. A. Alvarez and D. Suter, Phys. Rev. Lett. 104, 230403 (2010); Phys. Rev. A 84, 012320 (2011).

[3] G. A. Alvarez, R. Kaiser, and D. Suter, Ann. Phys. (Berlin) 525, 833 (2013).

Friday morning session I

Chairperson: A. Amo

Fri 2, 09:00 am

T30 – Fundamental limit for cooling in driven quantum systems

J. P. Paz [1], N. Freitas[1]
[1] *Departamento de Física, FCEyN UBA & IFIBA (UBA Conicet), Argentina*

I will study the asymptotic behavior of a class of quantum refrigerators consisting of a parametrically driven quantum network which is coupled with an arbitrary number of thermal reservoirs. I will show that this type of refrigerator can never cool a cold reservoir beyond certain minimal (non universal) temperature. The process that enforces this fundamental limit for cooling is very general: the non resonant creation of excitations pairs in the reservoirs. This process is closely related with the dynamical Casimir effect and seems to be the one responsible for the validity of the dynamical version of the third law of thermodynamics (Nernst unattainability principle)

Fri 2, 09:45 am

T31 – Experimental rectification of entropy production by a Maxwell's Demon in a quantum system

R. M. Serra[1,2]
[1] *Centro de Ciências Naturais e Humanas, Universidade Federal do ABC, Avenida dos Estados 5001, 09210-580 Santo André, São Paulo, Brazil .*[2] *Department of Physics, University of York, York YO10 5DD, United Kingdom.*

Maxwell's demon explores the role of information in physical processes. Employing information about microscopic degrees of freedom, this "intelligent observer" is capable of compensating entropy production (or extracting work), apparently challenging the second law of thermodynamics. In a modern standpoint, it is regarded as a feedback control mechanism and the limits of thermodynamics are recast incorporating information-to-energy conversion. We derive a trade-off relation between information-theoretic quantities empowering the design of an efficient Maxwell's demon in a quantum system. Supported by this trade-off relation and employing Nuclear Magnetic Resonance (NMR) spectroscopy, we set up an experimental coherent implementation of a measurement-based feedback. In this way the demon is experimentally implemented as a spin-1/2 quantum memory that acquires information, and employs it to control the dynamics of another spin-1/2 system, through a natural interaction. Noise and imperfections in this protocol are investigated by the assessment of its effectiveness. This realisation provides experimental evidence that the irreversibility on a non-equilibrium dynamics can be mitigated by assessing microscopic information and applying a feed-forward strategy at the quantum scale.

Friday morning session II

Chairperson: A. Amo

Fri 2, 11:00 am

T32 – Optomechanical non-linearities and wavelength conversion in semiconductor nano resonators

S. Anguiano[1], A. E. Bruchhausen[1], B. Jusserand[2], I. Favero[3], F. R. Lamberti[3,4], L. Lanco[4], I. Sagnes[4], A. Lemaître[4], N. D. Lanzillotti-Kimura[4], P. Senellart[4], and A. Fainstein[1,a]
[1]*Centro Atómico Bariloche & Instituto Balseiro, C.N.E.A., CONICET, 8400 S. C. de Bariloche, R. N., Argentina*
[2]*Institut des NanoSciences de Paris, UMR 7588 C.N.R.S. - Université Pierre et Marie Curie, 75015 Paris, France*
[3]*Université Paris Diderot, Sorbonne Paris Cité, Laboratoire Matériaux et Phénomènes Quantiques, CNRS-UMR 7162, 10 rue Alice Domon et Léonie Duquet, 75013 Paris, France* [4]*Centre de Nanosciences et de Nanotechnologies, C.N.R.S., Univ. Paris-Sud, Université Paris-Saclay, C2N Marcoussis, 91460 Marcoussis, France*

Applications of cavity optomechanics span from the development of novel strategies in gravitational wave detection to the study of nonclassical states of motion. The engineering of efficient resonators that support both mechanical and optical modes, showing strong interactions and reduced dimensions is at the heart of this field. Current technological and experimental approaches limit the accessible mechanical frequencies to a few GHz, imposing hard constraints on the study of mechanical quantum phenomena, and on the development of ultra-high frequency applications. We experimentally demonstrate 3-dimensional mechanical modes in the 20-100 GHz range in GaAs/AlAs micropillar cavities, operating in the near infrared range. These modes are evidenced through resonant pump-probe optical techniques that allow the optical probing of such high frequency mechanical modes in a dynamical way at the picosecond timescale. Optomechanical non-linearities are evidenced in these nano resonators together with dynamic optical wavelength conversion, suggesting the involvement of the latter as driving mechanism for the excitation of the resonator mechanical modes. Our results unlock a new frequency range in cavity nano-optomechanics. Moreover, these resonators are naturally integrable with quantum wells and quantum dots, leading to cavity quantum electrodynamic devices that can be optomechanically probed and controlled.

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POSTERS DQS2016

Posters

P1 – Many-body dynamics of the decay of excitons of different charges in a quantum dot

J. A. Andrade, A. A. Aligia, Pablo S. Cornaglia
Centro Atómico Bariloche and Instituto Balseiro, Comisión Nacional de Energía Atómica, CONICET, 8400 Bariloche, Argentina

We calculate the photoluminescence spectrum of a single semiconductor quantum dot strongly coupled to a continuum as a function of light frequency, gate voltage, and magnetic field. The spectrum is dominated by the recombination of several excitonic states which can be considered as quantum quenchs in which the many-body nature of the system is suddenly changed between initial and final states. This is associated with an Anderson orthogonality catastrophe with a power-law singularity at the threshold. We explain the main features observed experimentally in the region of stability of the trion X^-, the neutral exciton X0 and the gate voltage induced transition between them.

P2 – Quantum oscillations in Weyl semimetals via an effective surface theory

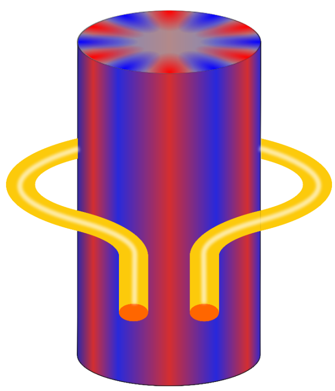
Jan Borchmann and T. Pereg-Barnea
Department of Physics and the Centre for Physics of Materials, McGill University, Montreal, Quebec, Canada H3A 2T8

In this work we construct an effective surface theory for a Weyl semimetal in a slab geometry. We apply this theory to the problem of Fermi arc induced quantum oscillations. Through this approach we are able to probe the system beyond the semiclassical limit and investigate the effect of small arc lengths on the phase offset of the quantum oscillations. In addition we find no contribution from the Berry curvature to the phase offset. Our findings are confirmed numerically via an exact diagonalization of a full lattice model for a Weyl semimetal slab. These serve as verification and extention of the semiclassical theory.

P3 – Dynamics and decoherence in non ideal Thouless quantum motors.

L. J. Fernández-Alcázar, H. M. Pastawsk, Raúl A. Bustos-Marún.
[1]*Instituto de Física Enrique Gaviola and Facultad de Matemática Astronomía y Física, Universidad Nacional de Córdoba, Ciudad Universitaria, Córdoba, 5000, Argentina.*

Different proposals for adiabatic quantum motors (AQMs) driven by DC currents have recently attracted considerable interest. However, the systems studied were often based on simplified models with highly ideal conditions and where the environment was neglected. Here we investigate the performance (dynamics, efficieny and output power) of a prototypical AQM, the Thouless motor. We study the deviations of this AQMs with respect to their simplified model based on a linearized Hamiltonian which neglects decoherence and the effect of the edges of the system. In order to correctly account for the environmental effects on this type of AQMS we extended our previous theory of decoherence in current induced forces to account for multiple site-dependent decoherent events. We provide analytical expressions for the current induced forces, friction coefficients and self correlation functions of the forces. We also prove that the model fulfill fluctuation dissipation theorem as well as Onsager's reciprocity relations. We find that decoherence drastically reduce the efficiency of the motor mainly due to the increase in conductance, while its effect on the output power is not so important. Interestingly, this type of AQM shows a memory effect of its quantum character, where even in the presence of high decoherence ratio it is possible to distinguish the effects of quantum mechanics on the efficiency. We also find that the effect of the edges of the system on the scattering matrix induces an additional conservative force that can dramatically alter its dynamics. We show that, within a certain range of voltages and friction coefficients, the system presents hysteresis with two limiting voltages that switch on-off its movement depending on its previous history.



Scheme of a possible Thouless motor made out of charges periodically arranged in the surface of a rotational piece. Rotation of the cylinder changes the potential sensed by the electrons along the wire.

P4 – Verifying fluctuation theorems for feedback controlled quantum systems

P. A. Camati[1] and R. M. Serra[1,2]
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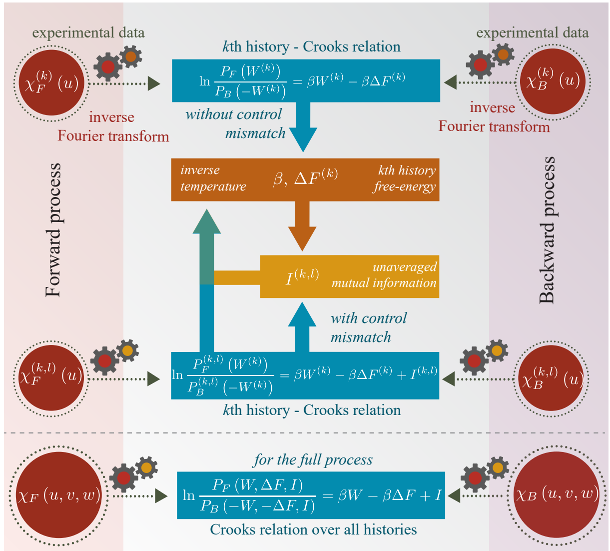
Thermodynamics deals with properties of macroscopic systems and as such the fluctuations of the thermodynamic quantities, e.g. work, acquire a definite value in the thermodynamic limit. When the system of interest is small, e.g. a Brownian particle, the fluctuations around the average become important. An important fluctuation theorem that applies to such systems is the Jarzynski relation $\langle \text{Exp}\,(-\beta W)\rangle = \text{Exp}\,(-\beta \Delta F)$, where β is the inverse temperature of the initial state of the system, W the stochastic work associated with a single realization of the driven protocol and ΔF free-energy difference between the final and initial time. This relation enables the inference of equilibrium free-energy differences from the average of a sample of nonequilibrium driven processes. The different nonequilibrium work values possess the probability distributions $P_F(W)$ and $P_B(W)$, for the forward and an appropriately defined backward process, respectively. Another fluctuation theorem, the Crooks relation, can be shown to be valid $P_F(W)/P_B(-W) = \text{Exp}\,[\beta(W - \Delta F)]$. The Jarzynski relation can be obtained from the more general Crooks relation. From the Jarzynski relation one can extract the second law of thermodynamics $\langle W\rangle \geq \Delta F$ which is valid for the average of stochastic processes. Therefore, the Crooks relation is seen as a generalization of the second law. These same relations also apply to individual quantum systems. The Maxwell's demon controls the dynamics of the system based upon the outcomes of an intermediate measurement. It employs a feedback control operation in order to rectify the entropy production or extract more work than would be possible otherwise. In order to understand such systems one has to consider the thermodynamic and information entropy on an equal footing. The quantum Crooks relation (also known as Tasaki-Crooks relation) has been extended to this feedback controlled protocols. We obtain two fluctuation theorems for this protocols: one is valid for each possible measurement outcome, $P_F^{(k,l)}\left(W^{(k)}\right)/P_B^{(k,l)}\left(-W^{(k)}\right) = \text{Exp}\left[\beta\left(W^{(k)} - \Delta F^{(k)}\right) + I^{(k,l)}\right]$, and other for the process as a whole, $P_F(W, \Delta F, I)/P_B(-W, -\Delta F, I) = \text{Exp}\,[\beta(W - \Delta F) + I]$, where I and $I^{(k,l)}$ are associated with the information extracted in the measurement. These fluctuation relations imply a generalized second law, $\beta\langle W - \Delta F\rangle \geq -\langle I\rangle$, where the informational quantity $\langle I\rangle$ appears explicitly in the second law together with the thermodynamic entropy production $\langle\sigma\rangle = \beta\langle W - \Delta F\rangle$. We devised a method based on a series of quantum circuits to verify experimentally the validity of these relation for a quantum system.



Method employed to verify the fluctuation relations for feedback processes. The experimental data are a series of characteristic functions obtained through the measurement of ancillas in different quantum circuits (not shown). From the characteristic functions one can obtain the different probability distributions by an inverse Fourier transform. From the distributions we evaluate the proper ratios in order to obtain the fluctuation relations and therefore estimate the relevant quantities: temperature, free-energies and mutual information density.

P5 – Quantum correlations and control of energy transport of a spin network

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The study of quantum many body systems has become a very active research topic, not only for interesting physics involved in the emergence of collective phenomena, but also for its potential applications in new quantum technologies. In this work, we study the transport properties of a externally controlled quantum network which is also affected by noise. We verify the role of quantum entanglement as a resource for the enhancement of energy transport and contrast it to the well known phenomenon of dephasing assisted transport. In fact, we show that for short observation times, entanglement assisted transport is more effective than the dephasing mechanism. For longer times, the situation is precise the inverse, i.e., the effect of having initial entanglement dissapear and dephasing assisted transport is fully manifested. We also provide a study about the survival of entanglement and discord in the system while transport is taking place.

P6 – Detection of Zak phases and topological invariants in a chiral quantum walk of twisted photons

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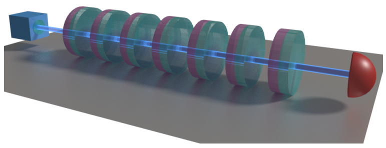
Recently, discrete time quantum walks have been shown to be a versatile platform to simulate topological phases. Quantum walks are periodically driven systems and can be described with the help of Floquet theory. Due to the periodicity in time, Floquet topological insulators are going beyond the standard classification of time-independent topological insulators and have to be characterized with different topological invariants [1]. We focus on the topological quantum walk realized experimentally in Ref. [2]. The latter is a 1D chiral quantum walk and, in this case, the Zak phase, the topological invariant, of 1D chiral topological insulators, does not fully describe the topology of a 1D chiral quantum walk and fails to predict the bulk-edge correspondence in. In particular, it does not predict the presence of topological edge states at energy $E = \pi$ (called anomalous edge states). However, as discussed in Ref. [3], the introduction of two timeframes U and $\tilde{U}$ (see Fig. 1) allows one to recover the bulk-edge correspondence by looking at the sum and the difference of the Zak phases of the two timeframes. We here propose a detection scheme of the Zak phase based on statistical moments. We then show the robustness of the method with respect to disorder. Finally, we report, up to our knowledge, the first experimental measurement of the bulk topological invariants of a 1D photonic chiral quantum walk [4].



Chiral Quantum walk: the light is passing through a repeated set of plates W and Q.

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P7 – Multilevel gate scheme for protected superconducting qubits

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The coherence time of superconducting qubits has been improved by more than five orders of magnitude over the last fifteen years. This astonishing rise has been possible thanks to the identification and partial suppression of noise sources, as well as to the engineering and exploration of new qubit designs. An example is the transmon qubit [Phys. Rev. A 76, 042319] which greatly suppressed the influence of low-frequency charge noise on the qubit coherence by design, flattening the energy spectrum as a function of the offset (noisy) charge. A radically different device, inspired in the topological protection paradigm, was proposed by Alexei Kitaev [arXiv:cond-mat/0609441]. The so called 0-pi qubit exploits symmetries and a non-local encoding of quantum information in order to behave robustly under several types of noise. However, this natural robustness makes its control more challenging. In our poster we introduce a novel gate scheme for the 0-pi, which is studied under realistic noise and circuit parameters.

P8 – Statistical Entropy of Open Quantum Systems

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Dissipative quantum systems are frequently described within the framework of the so-called "system-plus-reservoir" approach. In this work we assign their description to the Maximum Entropy Formalism and compare the resulting thermodynamic properties with those of the well - established approaches. Due to the non-negligible coupling to the heat reservoir, these systems are non-extensive by nature, and the former task may require the use of non-extensive parameter dependent informational entropies. In doing so, we address the problem of choosing appropriate forms of those entropies in order to describe a consistent thermodynamics for dissipative quantum systems.

P9 – Non ideal adiabatic quantum motors

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Recent proposals for adiabatic quantum motors (AQMs) driven by DC currents have found considerable interest. These models are often based on highly ideal conditions where environment is neglected. Here we investigate about the performance of AQMs which undergo friction, thermal fluctuations and decoherence of the current induced forces which drive the motor's motion. We provide analytical expressions accounting for environmental effects on forces and efficiency of the AQM. As a case of application, we evaluate the performance of an AQM based on Thouless pumping and we discuss deviations of the model under non ideal conditions. Our results should help to evaluate the feasibility of AQMs.

P10 – Universal mechanism for electron paramagnetic resonance of individual adatoms

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We propose a new universal mechanism that makes it possible to drive an individual atomic spin using a spin polarized scanning tunnel microscope (STM) with an oscillating electric signal. We show that the combination of the distance dependent exchange with the magnetic tip and the electrically driven mechanical oscillation of the surface spins permits to control their quantum state. Based on a combination of density functional theory and multiplet calculations, we show that the proposed mechanism is essential to account for the recently observed electrically driven paramagnetic spin resonance (ESR) of an individual Fe atom on a MgO/Ag(100) surface. Our findings set the foundation to deploy the ESR-STM quantum sensing technique to a much broader class of systems.

P11 – Fundamental limits for cooling of linear quantum refrigerators

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We study the asymptotic dynamics of arbitrary linear quantum open systems which are periodically driven while coupled with generic bosonic reservoirs. We obtain exact results for the heat flowing from each reservoir, which are valid beyond the weak coupling or Markovian approximations. We prove the validity of the dynamical third law of thermodynamics (Nernst unattainability principle), showing that the ultimate limit for cooling is imposed by a fundamental heating mechanism which dominates at low temperatures: the non resonant creation of excitation pairs in the reservoirs induced by the driving field. This quantum effect, which is missed in the weak coupling approximation, restores the unattainability principle whose validity was recently challenged.

P12 – Dimensional crossover in entanglement measures for the Calogero model

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The occupation numbers and von Neumann entropy for the two-particle Calogero model ground state was studied in one and two dimension as a function of the strength parameter. In the one-dimensional case, the von Neumann entropy is a non-monotonic function and have a finite value in the large interaction strength limit. Moreover, is possible to calculate these finite value from analytical expression. For the two-dimensional case, the isotropic and anisotropic confinement were studied. In the isotropic case, it was shown that the von Neumann entropy is a divergent function of the interaction strength parameter. For both one and two dimensional cases, the Schmidt decomposition of one particle system was deduced from the harmonic approximation. The von Neumann entropy behavior as a function of the anisotropy parameter was also studied. It was shown that in the isotropic confinement limit, the von Neumann entropy has a logarithmic divergence while for large values of the anisotropy parameter, the one-dimensional behavior is recovered, showing a dimensional crossover in this entanglement measure.

P13 – Coherent spectroscopy in Rubidium vapor with a high repetition rate femtosecond laser

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One of the most studied areas using ultrashort lasers is their interaction with atomic systems. Theoretical [1] and experimental [2,3] studies of rubidium (Rb) atomic vapor excited by low repetition rate mode-locked Ti:sapphire laser has been carried out. In this work, we extend these studies exploring the interaction of a high repetition rate, $1GHz$, femtosecond Ti:sapphire laser with atomic vapor. Under this high repetition rate, the atomic relaxation time is greater than the time interval between pulses and the necessary conditions for the coherent accumulation of population and coherence are much better fulfilled. The action of the ultrashort pulse train over different atomic velocity groups or over a selective group of Rb atoms is probed by a diode laser using velocity selective or repetition rate spectroscopies. Preliminary results of D_1 line of rubidium were described at reference [4]. Here we investigated the transmission of the diode laser when both lasers are tuned to D_2 line, $5S_{\frac{1}{2}} \rightarrow 5P_{\frac{3}{2}}$ transition. The experimental results show that the diode laser transmission increases or decreases depending on the mode of the frequency comb that interacts with different velocity groups. The experimental results are described in the frequency domain and the atomic system is modeled by a set of two three-level Λ systems and a system of two-level all independent and interacting with the frequency comb modes. The theoretical treatment considers the hyperfine transitions and distinguishes the interaction between the cyclic transitions from optical pumping effect, showing results in good agreement with the experimental data. This work was supported by the following Brazilian agencies: CNPq, Capes and Facepe.

[1] Felinto, D. et al. Coherent accumulation in two-level atoms excited by a train of ultrashort pulses. Opt. Commun., v. 215, 2003.

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[4] Moreno et al. Femtosecond 1 GHz Ti:sapphire laser as a tool for coherent spectroscopy in atomic vapor. J. Opt. Soc. Am. B, v. 28, 2011.

P14 – Coherent spectroscopy in rubidium vapor with a high repetition rate femtosecond laser

A. C. García-Wong [1], N. R. de Melo [1], A. A. C. de Almeida [1], S. S. Vianna [1]
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One of the most studied areas using ultrashort lasers is their interaction with atomic systems. Theoretical [1] and experimental [2,3] studies of rubidium (Rb) atomic vapor excited by low repetition rate mode-locked Ti:sapphire laser has been carried out. In this work, we extend these studies exploring the interaction with the atomic vapor and a high repetition rate, $1GHz$, femtosecond Ti:sapphire laser with Rb atomic vapor. Under this high repetition rate, the atomic relaxation time is greater than the time interval between pulses and the necessary conditions for the coherent accumulation of population and coherence are much better fulfilled. The action of the ultrashort pulse train over different atomic velocity groups or over a selective group of Rb atoms is probed by a diode laser using velocity selective or repetition rate spectroscopies. Preliminary results of D_1 line of rubidium were described at reference [4]. Here we investigated the transmission of the diode laser, with and without the presence of the ultrashort-pulsed laser, when both lasers are tuned to D_2 line, $5S_{\frac{1}{2}} \rightarrow 5P_{\frac{3}{2}}$ transition. The experimental results show that the diode laser transmission increases or decreases depending on the mode of the frequency comb that interacts with different velocity groups. The experimental results are described in the frequency domain and the atomic system is modeled by a set of two three-level Λ systems and a system of two-level all independent and interacting with the frequency comb modes. The theoretical treatment considers the hyperfine transitions and distinguishes the interaction between the cyclic transitions from optical pumping effect, showing results in good agreement with the experimental data. This work was supported by the following Brazilian agencies: CNPq, Capes and Facepe. [1] Felinto, D. et al. Coherent accumulation in two-level atoms excited by a train of ultrashort pulses. Opt. Commun., v. 215, 2003. [2] Aumiler, D. et al. Velocity selective optical pumping of Rb hyperfine lines induced by a train of femtosecond pulses. Phys. Rev. Lett, v. 95, 2005. [3] Ban, T. et al. Mapping of the optical frequency comb to the atom-velocity comb. Phys. Rev. A, v. 73, 2006. [4] Moreno et al. Femtosecond 1 GHz Ti:sapphire laser as a tool for coherent spectroscopy in atomic vapor. J. Opt. Soc. Am. B, v. 28, 2011.

P15 – Driving controlled entanglement in coupled flux qubits

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We study the possibility of manipulating quantum entanglement by periodic external fields. As an entanglement measure we calculate numerically the concurrence of two flux qubits coupled either inductively or capacitively and driven by a dc+ac magnetic flux. We show that it is possible to create or destroy entanglement in a controlled way by varying the parameters of the driving field.

P16 – Experimental control of entropy production in a spin based quantum engine

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We report the experimental implementation of a non-classical engine in a liquid-state nuclear magnetic resonance (NMR) setup, performing an Otto like cycle. This cycle consists of four strokes; compose for two processes without heat exchange, where an external time modulated magnetic field is applied to perform (extract) work on (from) the nuclear spin and two thermalization processes. During the thermalization, no external drive field is applied; there is only interaction with an emulated thermal medium. During a fast thermodynamic cycle, transitions between the different instantaneous energy eigenstates are unavoidable, which produce a kind of quantum friction bounding the protocol efficiency. This friction has been related as the non-equilibrium entropy production of the system. Exploiting a superadiabatic quantum driving, we find a non-transitional evolution, at finite time, without the need to satisfy the (quantum) adiabatic condition. This evolution allows us to improve considerably the performance of our quantum engine controlling the entropy production in the engine operation. In this way, we can extract the maximum work at a finite time leading to a greater power engine. In our experiment we present a full characterization of the energy fluctuations in the non-equilibrium operation of a quantum thermal machine, including the work and heat distributions in different configurations.

P17 – Floquet scattering of Dirac fermions and anomalous Goos-Hänchen shift in the presence of circularly polarized radiation

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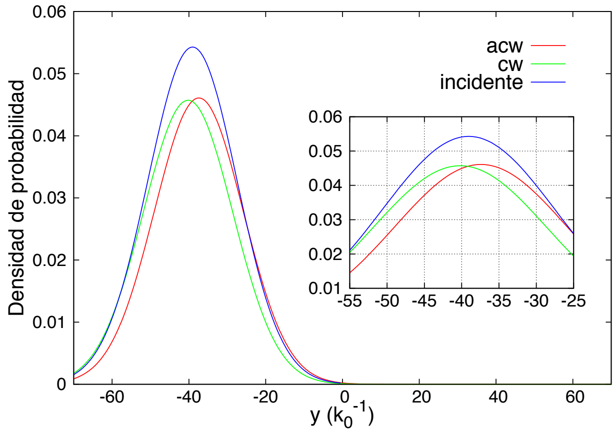
We study the inelastic scattering of massless Dirac fermions through regions irradiated with a circularly polarized laser field, using monolayer graphene as a physical realization of this system. The field is time dependent and also periodic in time so the so called Floquet method appears as a suitable tool. The scattering problem can be analized using different geometries in the boundaries separating irradiated and non irradiated regions, although the main features are common to all of them. We find chiral currents at the boundaries driven by the rotation of the vector field. We claim that these currents are ultimately responsible for an anomalous Goos-Hänchen-like shift present when studying the scattering of finite-size electron beams.



P18 – On-chip microwave circulators – Breaking time-reversal symmetry with Quantum phase slips

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Microwave Circulators are indispensable tools in contemporary experiments on nano-electronic and superconducting devices. The circulators currently used in experiments are macroscopic devices separate from the on-chip superconducting electronics. This poses a serious challenge to the future development of nanoelectronics as the increasing number of circulators used with an increasing number of microwave control and read-out lines requires an impractical amount of physical space in experiments. To address this issue, several proposals to integrate microwave circulators on-chip have been put forward in recent years. Here we consider a variation of the design in Ref. [1] using Quantum phase slip (QPS) junctions instead of Josephson junctions. QPS junctions are realized as thin long wires of disordered superconducting material. Since magnetic fields are suppressed in superconductors, superconducting wires constitute a barrier for the movement of magnetic flux-quanta. A quantum phase slip occurs when a magnetic flux-quantum tunnels coherently across this potential barrier. QPS junctions are then a dual circuit-element that are equivalent to Josephson junctions under the exchange of voltage and current [2] and they have recently been used to build a new type of superconducting flux-qubit [3]. In a QPS-junction based circulator, the three islands of the circulator correspond to superconducting loops with a given number of trapped flux quanta. The role of the symmetry breaking magnetic field is played by an external gate charge Q. As magnetic flux quanta do not interact with stray charges in the background, a QPS junction based design is much better isolated against the effects of charge noise than a Josephson junction based device. Here we present the properties of a QPS based circulator design from a Lagrangian description of the circuit. We use the obtained model to calculate the circulator efficiency of the system and study the effect of detrimental influences such as charge and magnetic flux noise and imperfections in the device fabrication.

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P19 – On skyrmion stability

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A skyrmion is a nanoscale vortex-like spin structure that is stabilized by the Dzyaloshinskii-Moriya interaction (DMI) in a chiral lattice helimagnet [1]. Because of their topological stability, small size, high mobility and extremely low depinning current they are considered, within the field of spintronics, as promising information carriers in topological based logic and data storage devices [2]. Usually skyrmions are described as circular domain walls, i.e. as axisymmetric spin configurations. One important question is whether skyrmions are stable under shape deformations, that could be caused either by interactions within a given material or by external action. We propose a general description for asymmetric skyrmions, which provides a theoretical framework to systematically study their stability under arbitrary deformations. In this context, the anisotropic skyrmion is parametrized by means of two well-known variational Ansätze, namely the Belavin-Polyakov skyrmion and the Bogdanov approximation. Our approach can be used to study the large anisotropic deformations of the skyrmion internal structure recently observed in B20-FeGe thin layers under anisotropic strain [3].

[1] J. H. Han et al., Phys. Rev. B **82**, 094429 (2010).

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[3] K. Shibata, et al., Nature Nanotech., **10**, 589-592 (2015).

P20 – Fock-state superradiance in cold atoms

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We implement an experimental setup for photon-pair generation from atomic ensembles of rubidium trapped and cooled in a magneto optical trap (MOT), in a configuration as proposed in the DLCZ quantum information protocol. We detect and characterise the photons generated and we observe nonclassical correlations between these optical fields. By using a method based on microwave spectroscopy we cancel the spurious magnetic fields acting on the MOT, so that we obtain results in absence of magnetic fields. We compare the results of the experiment with a theory for the wavepacket of the extracted photon and a good quantitative agreement is obtained. In addition, we observe the superradiance nature of such a process in the regime of single-photon and two-photon states.

P21 – Quantum chopping of microwave signals

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Driving in open quantum optical systems is often dealt with by using the separation of energy scales in those systems and employing the rotating wave approximation. We propose a superconducting microwave experiment where the coupling between a transmission line and a nonlinear element can be driven by a classical current – hence making it possible to realise a variety of driving procedures where effective theories become insufficient. Instead, we solve the dynamics exactly in the weakly coherent limit by use of a Floquet scattering theory. One key finding is different diabatic interference effects (quantum chopping) and a induced changing of the photon statistics. The results extended to strongly coherent incoming signals in a Master equation approach, where e.g. the non-trivial change of the power spectrum can be obtained.

P22 – Photo-electrons unveil topological transitions in graphene-like systems

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The topological structure of the wavefunctions of particles in periodic potentials is characterized by the Berry curvature Ω_{kn} whose integral on the Brillouin zone is a topological invariant known as the Chern number. The bulk-boundary correspondence states that these numbers define the number of edge or surface topologically protected states. It is then of primary interest to find experimental techniques able to measure the Berry curvature. However, up to now, there are no spectroscopic experiments that proved to be capable to obtain information on Ω_{kn} to distinguish different topological structures of the *bulk* wavefunctions of semiconducting materials. Based on experimental results of the dipolar matrix elements for graphene, here we show that ARPES experiments with the appropriate x-ray energies and polarization can unambiguously detect changes of the Chern numbers in dynamically driven graphene and graphene-like materials opening new routes towards the experimental study of topological properties of condensed matter systems.

P23 – Optimal control of many-body quantum dynamics: Chaos and complexity

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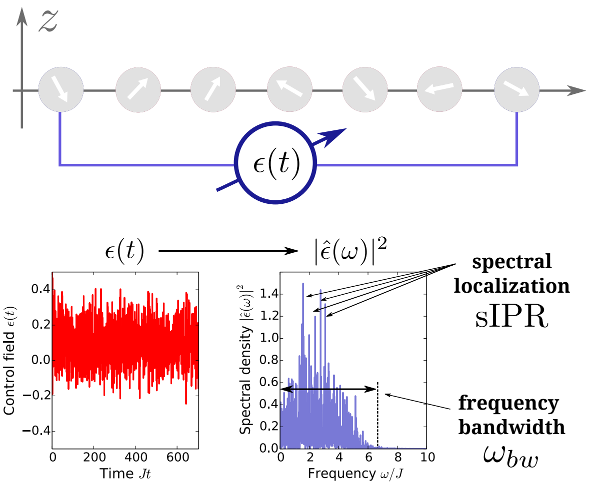
Achieving full control of the time-evolution of a many-body quantum system is currently a major goal in physics. In this work we investigate the different ways in which the controllability of a quantum system can be influenced by its complexity, or even its chaotic properties. By using optimal control theory, we are able to derive the control fields necessary to drive various physical processes in a spin chain. Then, we study the spectral properties of such fields and how they relate to different aspects of the system complexity. We find that the spectral bandwidth of the fields is, quite generally, independent of the system dimension. Conversely, the spectral complexity of such fields does increase with the number of particles. Nevertheless, we find that the regular or chaotic nature of the system does not affect significantly its controllability.



P24 – Electron-correlation driven capture and release in double quantum dots

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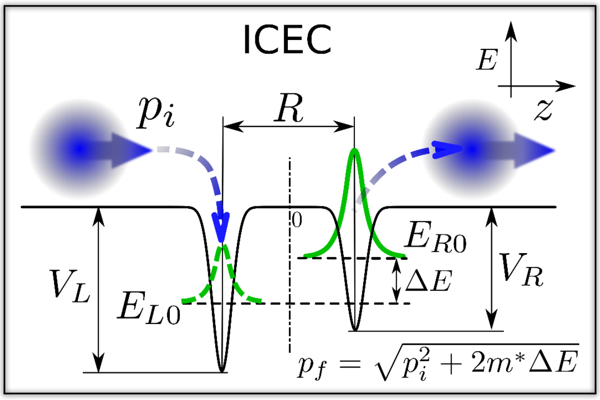
We recently predicted that the interatomic Coulombic electron capture (ICEC) process, a long-range electron correlation driven capture process, is achievable in gated double quantum dots (DQDs). In ICEC an incoming electron is captured by one quantum dot (QD) and the excess energy is used to remove an electron from the neighboring QD. In this work we present systematic full three-dimensional electron dynamics calculations in quasi-one dimensional model potentials that allow for a detailed understanding of the connection between the DQD geometry and the reaction probability for the ICEC process. We derive an effective one-dimensional approach and show that its results compare very well with those obtained using the full three-dimensional calculations. This approach substantially reduces the computation times. The investigation of the electronic structure for various DQD geometries for which the ICEC process can take place clarify the origin of its remarkably high probability in the presence of two-electron resonances.



Schematic view of the interatomic Coulombic electron capture for a double quantum dot. The effective mass approximation is used to describe the quantum dots as two potential wells. The capture of the incoming electron by the left dot (dashed green state) is mediated by its correlation with the electron initially bound to the right dot (full green state). While the electron is captured in the left dot, the electron on the right is excited into the continuum and becomes an outgoing electron.

P25 – Quantum memories based on dark state polaritons in semiconductor nanoestructures

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The Electromagnetically Induced Transparency is an optical phenomenon that emerges from pump-probe experiments with three level atomic systems. This allows to achieve special light-matter excitations called Dark State Polaritons which are useful to store and retrieve the light. Here we present a study of the dark state polaritons in charged quantum dots, quantum dot molecules and double quantum wells. Also, we numerically solve the Heisenberg-Langevin equations describing the propagation of a light pulse in the EIT medium and we examine how this can work as a quantum memory storing quantum states of light. Finally, we study the dark state polaritons in optomechanical systems for a future implementation of quantum memories with hybrid systems based in quantum dots embedded in optomechanical microcavities.

P26 – Driven open quantum systems and Floquet stroboscopic dynamics

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We provide an analytic solution to the problem of system-bath dynamics under the effect of high-frequency driving that has application in a large class of settings, such as driven-dissipative many-body systems. Our method relies on discrete symmetries of the system-bath Hamiltonian and provides the time evolution operator of the full system, including bath degrees of freedom, without weak-coupling or Markovian assumptions. An interpretation of the solution in terms of the strobo- scopic evolution of a family of observables under the influence of an effective static Hamiltonian is proposed, which constitutes a flexible simulation procedure of non-trivial Hamiltonians. We instan- tiate the result with the study of the spin-boson model with time-dependent tunneling amplitude. We analyze the class of Hamiltonians that may be stroboscopically accessed for this example and illustrate the dynamics of system and bath degrees of freedom

P27 – Transport through an AC driven impurity: Fano interference and bound states in the continuum

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Using the Floquet formalism we study transport through an ac-driven impurity in a tight binding chain. The results obtained are exact and valid for all frequencies and barrier amplitudes. At frequencies comparable to the bulk bandwidth we observe a breakdown of the transmission $T = 0$ which is related to the phenomenon of Fano resonances associated to AC-driven bound states in the continuum. We also demonstrate that the location and width of these resonances can be modified by tuning the frequency and amplitude of the driving field. We also demonstrate that at high frequencies there is a close relation between the resonances and the phenomenon of coherent destruction of tunnelling. For very low frequencies, as expected, our results approach a simple time average of the static transmission. We also discuss a generalization of these results that includes two spin channels, a local Zeeman splitting and interaction at the impurity site.

P28 – Quantum Phase Slips in Topological Josephson Junction rings

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Over the last years, the search for Majorana fermions has been an active area of Condensed Matter physics. Despite encouraging experimental results, the existence of Majoranas has not been unequivocally proven. One of signatures of Majoranas is the existence of 4π periodic charge e tunneling between topological superconductors, known as Majorana assisted tunneling. In this work, we study how the inclusion of Majorana assisted tunneling modifies the physics of quantum phase slips 1D Josephson junction rings. In addition, we study parity breaking processes in a controlled manner by coupling the ring to a single level system. For the ring alone, we find that the effects of the 2π periodic terms are suppressed by increasing the number of islands in the ring allowing a clearer distinction of the 4π periodicity. In the combined system, we find that the periodicity can be tuned by controlling the separation of the single level system. We also discuss the signatures of Majoranas left after parity breaking effects restore the 2π periodicity.

P29 – Quantum to classical transition in the work distribution for chaotic systems

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The work distribution is a fundamental quantity in nonequilibrium thermodynamics mainly due to its connection with fluctuations theorems. Here we develop a semiclassical approximation to the work distribution for a quench process in chaotic systems. The approach is based on the dephasing representation of the quantum Loschmidt echo and on the quantum ergodic conjecture, which states that the Wigner function of a typical eigenstate of a classically chaotic Hamiltonian is equidistributed on the energy shell. We show that our semiclassical approximation is accurate in describing the quantum distribution as we increase the temperature. Moreover, we also show that this semiclassical approximation provides a link between the quantum and classical work distributions.

P30 – A photonic quantum diode using superconducting qubits

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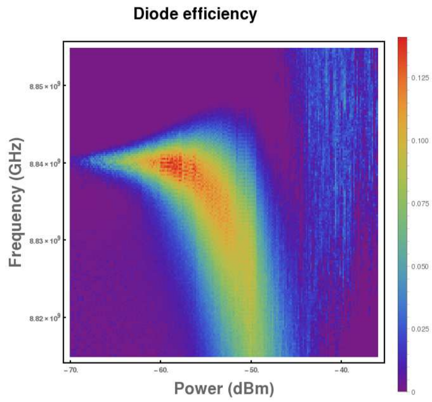
Strong coupling between quantum emitters and photons in a one-dimensional waveguide is a key element for waveguide quantum electrodynamics (QED), a regime of great interest for universal quantum computing and communication. The basic ingredient of waveguide QED, a single two-level system (TLS) in a waveguide, can behave as a mirror whose transparency depends on the frequency and power of the incoming radiation. In this work we present our experimental results on the system consisting of two superconducting transmon-like qubits embedded in a copper waveguide realizing an analogue of a Fabry-Pérot interferometer. Two external coils provide control over the flux threading the transmons, thus allowing us to individually tune their transition frequencies and to change the effective distance between the mirrors *in situ*. By exploiting the quantum properties of the mirrors we achieve new functionalities of the interferometer. Most notably, when the TLSs are asymmetrically detuned with respect to the frequency of the incident radiation, the system exhibits previously unobserved non-reciprocal behavior and operate as a microscopic light diode.



Diode efficiency. The plot indicates the diode efficiency which quantifies the degree of non-reciprocity of the interferometer formed by two qubits in the waveguide. During the measurement the frequencies of qubits were kept constant throughout the experiment. To measure efficiency the transmission through the interferometer was recorded in forward and reversed directions of the incident radiation for different powers. The diode efficiency is proportional to the difference of the absolute value squared of forward and reversed transmissions divided by their mean value.

P31 – Radial Order Selection Rule in Sum of Orbital Angular Momentum of Light

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As seem in previous works[1], by using Laguerre-Gaussian modes in second harmonic generation it is observed the conservation of the orbital angular momentum, making it possible to generate a third beam that has the topological charge equal to the sum of the topological charges of two coherent beams. In further inspection we observe that is possible to obtain a selection rule for the radial orders as well, that is related to the sign of product of the topological charges of the generating beams.

P32 – Optimal control of 1D Bose-Einstein condensates

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d
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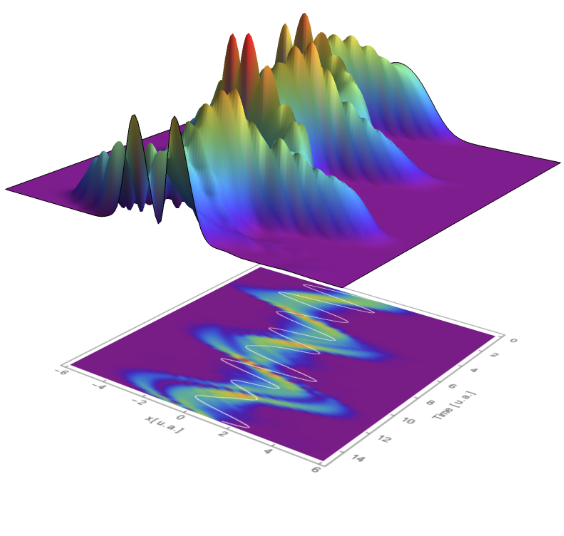
The ability to lead a quantum system from a given state to one with desired properties as can be: Entanglement, defined angular momentum, etc.; and how to do it, for example minimizing time to avoid decoherence, is of vital importance in the development of technologies for quantum information processing. In this work we show the implementation of the chopped random basis optimal control technic (CRAB)[1] in the context of multiconfiguracional time dependent Hartree for bosons-fermions theory (MCTDH-X)[2, 3]. We will describe applications examples, and show current work in progress in ultracold atoms systems.



Top: Density plot $\rho(x,t)$; Botton: Projected Density plot and control pulse $\Gamma(t)$ (white line). At $t=0$ the system begins with the density of a condensate, after the time evolution the density was drive into a close one that corresponds to the second excited state with $f(\Gamma, |\psi(T))=0.00225$.

[1] Phys. Rev. Lett. 106, 190501 (2011).

[2] Phys. Rev. A 93, (2016);http://ultracold.org.

[3] Nature Physics 7, 608611 (2013); Phys. Rev. A 92, 062110(2015).

P33 – Corrections to the Berry phase in a solid-state qubit due to low-frequency noise

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We present a quantum open-system approach to analyze the nonunitary dynamics of a superconducting qubit when it evolves under the influence of external noise. We consider the presence of longitudinal and transverse environmental fluctuations affecting the system's dynamics and model these fluctuations by defining their correlation function in time. By using a Gaussian-like noise correlation, we can study low- and high- frequency noise contribution to decoherence and implement our results in the computation of geometric phases in open quantum systems. We numerically study when the accumulated phase of a solid-state qubit can still be found close to the unitary (Berry) one. Our results can be used to explain experimental measurements of the Berry phase under high-frequency fluctuations and design experimental future setups when manipulating superconducting qubits.

P34 – Remnant Geometric Hall response in a Quantum Quench

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Out-of-equilibrium systems can host phenomena that transcend the usual restrictions of equilibrium systems. Here we unveil how out-of-equilibrium states, prepared via a quantum quench in a two-band system, can exhibit a nonzero Hall-type current—a remnant Hall response—even when the instantaneous Hamiltonian is time reversal symmetric: a stark contrast with equilibrium Hall currents. Interestingly, the remnant Hall response arises from the coherent dynamics of the wave function that retain a remnant of its quantum geometry postquench, and can be traced to processes beyond linear response. Quenches in two-band Dirac systems are natural venues for realizing remnant Hall currents, which exist when either mirror or time-reversal symmetry are broken (before or after the quench). Its long time persistence, sensitivity to symmetry breaking, and decoherence-type relaxation processes allow it to be used as a sensitive diagnostic of the complex out-of-equilibrium dynamics readily controlled and probed in cold-atomic optical lattice experiments.

P35 – Criticality of environmental information obtainable by dynamically controlled quantum probes

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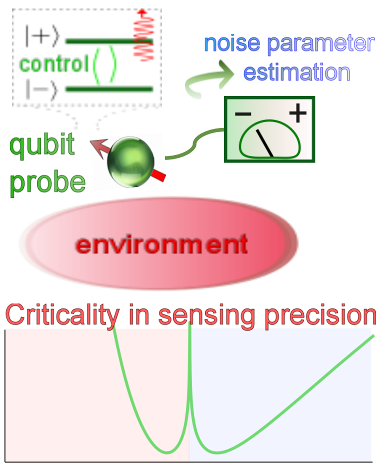
A universal approach to decoherence control combined with quantum estimation theory reveals a critical behavior, akin to a phase-transition, of the information obtainable by a qubit-probe concerning the memory time of environmental fluctuations of a generalized Ornstein-Uhlenbeck processes. The criticality emerges only when the probe is subject to suitable dynamical control aimed at inferring the memory-time. A sharp transition is anticipated between two dynamical phases characterized by either a short or long memory-time compared to the probing-time. This phase-transition of the environmental information is a fundamental feature that characterizes open quantum-system dynamics and is important for attaining the highest estimation precision of the environment memory-time under experimental limitations.



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