Efficient driven interactions in composite few-body systems

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In this work, we studied an efficient way to dynamically couple an interacting few body system. We propose doing this by quickly ramping a Feshbach resonance such that the initially non-interacting particles reach a final strongly interacting state. This is usually difficult to realize due to out-of-equilibrium excitations created in the system during the ramping process. One way to overcome this is through shortcuts to adiabaticity, which aim to reduce these unwanted excitations and ensure that we reach the target state in a short time. Particularly, we analyzed the case of three interacting harmonically trapped bosons confined to a one-dimension, where we have 2 subsystems: two particles of species A and one particle of a different species B. We used a variational approach to design a Feschbach pulse between the particles in such a way that we could drive the system from a completely non-interacting state to an arbitrary few body strongly interacting state. Naturally, since the system has two different interactions (between the A particles and between the B particle and the A particles), there are several ways in which one could drive the system to a final state. We compare these different sequences of pulses and we show a simple way to decide the best protocol which allows us to reach the target state. The efficiency of the STA is quantified by analyzing the irreversible work which quantifies the excess excitations in the system, and by comparing the reduced density matrix of each subsystem to that of the desired target state. We also compare the STA to a reference drive that has not been optimized, which highlights how our approach improves the efficiency of the driving.

Effective Spin Hamiltonians for Negatively Charged NV Centers

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Over the last decades, the NV center has emerged as a promising candidate in many applications, including metrology. To be able to understand this particular application it is important to understand the dynamics of the electronic spin under different kinds of fields. However, this has proven difficult, with many different interpretations across different authors. Recent experiments have been able to access degrees of freedom of singular subspaces of the electronic spin such as the ground state, although its dynamics are affected by several other states in the system. Here, we present a procedure that encompasses the effect all the higher states in the system to formulate a non-diagonal effective Hamiltonian of the ground state triplet. The present results have important implications for applications in nanomagnetometry.

Using a Quartz Crystal μ–balance for measuring atomic velocities in a "Spin- Flip" Zeeman Slower

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The possibility to control with high precision the position of the atoms in a crystal structure is one of the biggest dreams of anyone who studies surface science and crystallography. In order to achieve this, our goal is to merge the tools of quantum-optics physics and ultra-cold atoms with solid-state physics and surface science, implementing a three dimensional array optical lattice for the study of crystallographic properties by means of low energy electron diffraction. Therefore, a new field of research in the borderland between this areas of the physics will enable highly sensitive tests of postulates from fundamental physics. For this purpose, we create an experimental apparatus consists of a Gd atoms source and 1 m-long multi-layer solenoidal "Spin-Flip" Zeeman slower, designed to produce an atomic beam flux of approximately 10^12 atoms/s at the speed of around 30 m/s [1]. And in order to fully characterize the energy exchange of the Gd atoms in their physical vapor state, we present an alternative method based on the careful observation of perturbations induced by interaction of particles with the oscillation frequency of a Quartz Crystal μ-balance (QCM), normally used in the thin films deposition process in solid-state physics. We observe that the natural oscillation frequency of the QCM is not only perturbed by the mass deposition but also by the momentum exchange of the particles when they hit the crystal surface, and through the careful measurement of these perturbations we can determine the kinetic energy of the atoms and its energy distribution [2]. In this experiment, we focus a 442,6 nm laser into a counter-propagating beam of Gd atoms in order to drive the strongest dipole atomic transition from the ground to the excited state and measure the variations of the velocity of the atoms at the end of the Zeeman Slower. We obtain a preliminary results of 56% reduction of the velocity of the Gd atoms respect to their initial velocity. Usign a current of 4,0 A in the Zeeman coils.

[1]. M. Guevara-Bertsch, L. Salfenmoser, A. Chavarria-Sibaja, E. Avendaño, O.A. Herrera-Sancho (2016). "Diseño y caracterización de un enfriador de átomos de tipo desacelerador Zeeman". Revista mexicana de fisica, 62(2), 175-182.

[2]. M. Guevara-Bertsch, A. Chavarría-Sibaja, A. Godínez-Sandí, O.A. Herrera-Sancho (2018). "Energy exchanges between atoms with a quartz crystal μ-balance".

Quantum Entanglement in Composite Particle Systems

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From second quantization of quantum mechanics, we know the bosonic behaviour of a particle can be expressed by commutation relations of creation and annihilation operators as $[a,a^\dagger]=1$. For composite particles consisted of two fundamental particles, however, the commutation relation is given by $[c,c^\dagger]=1+\Delta$, so minimizing Δ means the composite particle behaves as an ideal boson. In 2005, Law[1] found that $\Delta\rightarrow 0$ when the Schmidt number, which is a measurement of entanglement, is much greater than the total number of composite particles in the system. His work was generalized in 2010 by Chudzicki, Oke and Wootters[2], they used purity as a measurement of entropy and didn't need to specify the form of the wave function for the composite particle. In this project we want to generalize the previous works for systems consisting of fermionic composite particles. Moreover we are interested in investigating if entanglement can help us to understand percolation phase transitions as a function of the density of particles. Generalizations to relativistic systems require a different approach for calculating entanglement entropy using quantum field theory techniques, as described by Nishioka[3].

[1] https://doi.org/10.1103/PhysRevA.71.034306

[2] https://doi.org/10.1103/PhysRevLett.104.070402

[3] https://doi.org/10.1103/RevModPhys.90.035007

Continuous observation of matter wave Bloch oscillations for gravitational sensing

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The purpose of this work is the continuous observation of matter wave Bloch oscillations for gravitational sensing. Atom interferometry with cold matter waves is currently revolutionizing top end precision metrology and force sensing. A particularly attractive interferometric technique for gravity measurement translates the gravitational acceleration into a frequency measurement of Bloch oscillations of laser-cooled atoms confined in a stationary vertical light wave. To probe these dynamics we will use a cold cloud of strontium atoms confined in a ring cavity, the task of which is to amplify the interaction between the atoms and the light and to provide a collective response.

Hollow Bessel beams for guiding cold atoms

between vacuum chambers with

magneto-optical traps

Yahaira Dalila Rivero Jerez

(IFSC)

The research project is part of the construction of a high precision atomic interferometry gravimeter.The first stage of the experiment consists on the set up to obtain the cloud of cold atoms, where Sr atoms are evaporated, decelerated and confined in a two-dimensional optical magneto trap (MOT-2D) and from there are thrown to a second trap we call MOT-3D with the help of a pushing beam. The transfer of the atoms between the two cavities presents some experimental difficulties, such as the small opening between them and the angle of inclination that separates them, the latter becomes a big problem when aligning the MOT-2D with the pushing beam to simultaneously caught the atoms in the second cavity by the 3D MOT. Aiming at a way to overcome this drawback, and as part of a joint project between EESC and IFSC, we are implementing the construction of a Hollow Bessel Beam tuned to the blue side of an atomic transition that will have two main utilities, guiding the atoms through the small space between the cavities and depositing them in the 3D trap zone as well as preventing the atoms from clinging to the tunnel walls being guided by the repulsive force of the potential created by the light of the beam. The quasi-Bessel hollow beam present some experimental advantages, among them the main one is the ability to form a non-diffractive zone, that is, a constant potential over a specific distance; another important property is the reconstruction of the beam after finding obstructions which will greatly facilitate the calibration thereof at the moment of implementation without impairing or decreasing the count of atoms present in the cavities.

Electromagnetic behavior of the relativistic Fermi gas

Daniel Medeiros Reis

(Centro Brasileiro de Pesquisas Físicas)

The knowledge of the responses of a relativistic electron gas (REG) at flnite temperatures and densities to electromagnetic (EM) radiation is a useful tool for understanding the physics of several systems, as in condensed matter physics as also astrophysical scenarios. Investigations of the response of a REG to the action of an external electromagnetic perturbation have many similarities with studies in the flelds of photonics and plasmonics, where it is crucial to understand the propagation of EM and plasmonic modes that are also present in the REG. In photonics and plasmonics one normally uses phenomenological expressions for the responses of the media of interest. Here, however, one may actually compute such responses from flrst-principles, so that we envisage applying our techniques in the future to the actual computation of the responses of artiflcially constructed materials. Using quantum electrodynamics at flnite temperatures, we describe electromagnetic propagation in a REG at flnite temperatures and carrier densities and obtain electric and magnetic responses and general constitutive relations. Rewriting the propagator for the electromagnetic fleld in terms of the electric and magnetic responses, we identify the modes that propagate in the gas. As expected, we obtain the usual collective excitations, i.e., a longitudinal electric and two transverse magnetic plasmonic modes. In addition, we flnd a purely photonic mode that satisfles the wave equation in vacuum, for which the electron gas is transparent. We present dispersion relations for the plasmon modes at zero and flnite temperatures and identify the intervals of frequency and wavelength where both electric and magnetic responses are simultaneously negative, a behavior previously thought not to occur in natural systems.

Ground State of Fermions in Quasi-1D Honeycomb Optical Lattices

Daniel Padilla-González

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Lattice models (tight-binding) for many-body systems give a good theoretical and experimental framework to study quantum phase transitions presented in several strongly correlated materials at low temperature. In general, those phase transitions are driven by a fine-tuning of non-thermal parameters such that each phase is determined by a fixed energy scale. In particular, the \textit{ Ionic Hubbard model} allows to study crystalline bipartite lattices where the possible phase transitions are induced by a competition between the on-site interaction U and the geometry of the lattice itself given by the staggered potential Δ. Furthermore, recently experimental and theoretical works on honeycomb lattice connect the model with phenomenon like unconventional superconductivity [Journal of the Physical Society of Japan 82 (2013) 034704] and topological correlated systems [PhysicaB 481 (2016) 53-58]. Motivated by this, we study the ground-state properties of the Ionic Hubbard model on a narrow honeycomb lattice regarding it as a quasi 1D lattice using a simple DMRG finite algorithm.

Quantum correlations in the Mollow triplet and its higher-harmonic sidebands

Elnaz Darsheshdar

(University Federal Sao Carlos)

The Mollow triplet corresponds to the inelastic scattered light by a strongly driven atom, and presets a triplet of spectral lines: one around the laser frequency and two symmetric ones shifted by Rabi frequency. The light-mediated dipole-dipole interactions between atoms, leads to appearance of additional side bands in the spectrum, in twice the Rabi frequency from the carrier. These sidebands are a quantum cooperative effect, as they require the presence of quantum pair correlations. Correlations between the photons emitted in the two single-atom sidebands have been studied experimentally and theoretically . We here discuss quantum correlations between the photons emitted in the interaction-induced sidebands, and also from these new sidebands and the single-atom ones. These correlations makes cold atom systems promising sources of heralded photons, and interactions may provide an opportunity to control them.

Population control of NV ensemble using advanced microwave pulses

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In this work we study the dynamics of the electronic spin population in the ground state of Nitrogen-Vacancy (NV) ensemble, when it is disturbed by a linearly chirped pulse in order to achieve effective population inversion or a coherent superposition of states. In both cases, we create pulses by inverse engineering method and comparing it with the conventional method of a square microwave pulse with constant frequency, and we highlights the significant improvements.

NON-LINEAR REFRACTION INDEX FROM THE CISON D1 LINE

Felipe Cesar Dias dos Santos

(Universidade Federal da Paraíba)

In the interaction of a laser with an atomic vapor it is observed that at high intensities of the light beam, the refractive index of the vapor depends on the intensity of this beam. For low saturated atomic vapor the refractive index varies linearly with the beam intensity: n = n0+n2I; with the Kerr coefficient n2 proportional to the third order vapor susceptibility and I the beam intensity. There is a very simple technique that allows to measure the Kerr coefficient n2. This well-known technique is called z-scan and consists of varying the position of the atomic vapor along the axis of propagation of a focalized beam and detecting its intensity after an aperture. Then, the relationship between the intensity transmitted by the apperture and the vapor position, first presented by Sheik-Bahae in 1990 [1], is used to measure the nonlinear refractive index of the vapor transition. We used the z-scan technique to measure n2 on the D1 line of Cesium (wavelength 895 nm). In parallel, we set up a saturated absorption experiment that allows to monitor the frequency of the laser. We have been able to observe the intensity profile that corresponds to the z-scan signature and are extracting the corresponding n2 values. Our next step is to compare the obtained n2 for different laser frequencies and with those from theoretical calculations using a model for a three-level system that we are develloping. To date, we have no knowledge of any measure of n2 in this transition. We will present here the set-up used in the experiment, the experimental intenisty profiles and preliminary comparison of the obtained Kerr coefficient with theoretical calculations.

[1] SHEIK-BAHAE, M; SAID, Ali A; WEI, Tai-Huei, HAGAN David J. & VANS STRYLAND, E. W. \textit{Sensitive measurement of Optical Nonlinearities Using a Single Beam.} Journal of Quantum Electronics \textbf{26}, 760 (1990).

Decoherence and collective effects of quantum emitters near a medium at criticality

Felippo Marvila D' Angelis

(UFRJ)

We investigate the influence of phase transitions on the behavior of collective quantum emission. We discuss two distinct physical processes, the center-of-mass decoherence of a single emitter, and the collective emission of two emitters, addressed with an unified formalism relying on standard perturbation theory. Two specific examples of phase transitions are considered: the percolation transition in a metal-dielectric composite, and the metal-insulator transition in VO2. The decoherence and the collective emission rates can be decomposed as a sum of two contributions, accounting for the spontaneous emission and for interference effects, respectively. The former is enhanced by the Purcell effect for emitter(s) in the vicinity of the critical medium. The latter, associated with quantum interferences, experiences a “sudden death” near the critical point of the phase transition. Our findings unveil the interplay between the Purcell and collective effects and its dependence on metal-insulator transitions. In the case of VO2, decoherence and collective emission rates exhibit a characteristic hysteresis that strongly depends on the material temperature. These results, based on experimental data, suggest that VO2 could be explored as a versatile material platform where decoherence and collective emission can be tuned by varying the temperature.

Temperature sensing with NV centers nanocrystals attached to optical fibers

Francisca Ignacia Sáez Puentes

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Diamonds with nitrogen vacancy centers coupled to the end of an optical fiber will be used to measure the temperature inside of mice brains in vivo, specifically in the hippocampus. The temperature will be mesured using Electron Spin Resonace (ESR), correlating the change in the zero field splitting with the temperature fluctuations inside the brain. The assembly of the optical configuration was tested and it was demonstrated that it is suitable for ESR. A microwave antenna adjusted to the optical fiber was built and optical trapping is used to attach the diamonds to the core of the fiber with UV glue.

Modelling a quantum measurement process

Gabriel Dias Carvalho

(Centro Brasileiro de Pesquisas Físicas)

Quantum theory is undoubtedly a successful physics theory: it is consistent, its mathematical formalism is well founded and the laws that govern the small scale phenomena are, mostly, well described by quantum theory. However, in our daily lives we do not experience quantum phenomena. Classical physics is well enough to describe the daily world. In this thesis we use quantum information theory tools, particularly quantum channels, to contribute to the search for an answer to the question: what is the real role/importance of the impossibility of accessing all the degrees of freedom of a quantum system to emergence of the effective, "classical", realm and, parallel, the "death" of quantum features? Such impossibility is translated mathematically via a coarse-graining quantum channel. We start by developing a framework to investigate what kinds of dynamics emerge when one does not have full access to the degrees of freedom of a given system. As an application of the developed general framework, we present attempts to model a quantum measurement process: a system to be measured consisting of a qubit in a superposition interacts with a measuring apparatus consisting of a spin coherent state (first attempt) and a N qubit state (third attempt). Looking at the emerging, effective description of the apparatus, we were able to recover the superposition coefficients of the system (in both attempts). In the first attempt, we were also able to visualize the death of quantum correlations between system and apparatus and the creation of classical ones. In the third, we managed to observe the death of quantum coherences in the apparatus' effective state, obtained through the coarse-graining action. A situation akin to decoherence, although it was not necessary to evoke any interaction with the surrounding environment.

Radidly rotating Bose-Einstein condensates in a bubble trap

Guilherme Tomishiyo Teixeira de Sousa

(Instituto de Física de São Carlos)

Bose-Einstein condensates (BECs) in dilute cold gases are appealing systems to study superfluid vorticity. If enough angular momentum is imparted to the fluid, it is expected that the physics maps to a quantum Hall effect physics where a wave function of the Lowest Landau Level (LLL) type is expected to describe the condensate. Experimental verification is complicated, however, because rotation weakens the effective potential of typical harmonic traps used to confine the gas. Seeking to address this issue, anarmonic potentials have been proposed. The bubble trap is a special kind of such a type of potentials, because it allows for manipulation of the topology of the system: by changing the potential parameters, one can study the condensate in a filled or a hollow sphere scenario. In this work, we seek to deepen theoretical knowledge about the behavior of the condensate in bubble trap potentials, with special emphasis in the collective modes of the vortex array.

The κ-Jaynes-Cummings

Gustavo Mehanna Uhdre

(Universidade Estadual de Ponta Grossa)

In this work we do a description of system κ-Jaynes-Cummings through of κ-Dirac oscillator. The κ-Dirac equation, derived of $\kapaa$-Poincaré-Hopf algebra provides us a Hamiltoniano PT-symetry. Using a similarity transformation we can study the effects of deformation on the observables of the system, like the conservation of angular moment, and colapses and revival of coherent states

Simulation of the dynamics of ultracold gases via the Boltzmann Equation

Hiram Epifânio Júnior

(UFRN)

We simulate the dynamics for a system of ultra cold particles from a generic non-equilibrium state and let it thermalize to the Maxwell-Boltzman distribution. We then perform a set of reliability tests to check the code and apply it to the description of the collective modes in a harmonic potential, such as the sloshing and breathing modes. We intend to generalize the method to the description of fermions and bosons with long-range interaction.

Coherence in a quantum Bell state and its analogue in classical physics

Jeimmy Alejandra Alarcon Carvajal

(Universidad Nacional de Colombia - Sede Bogotá)

The comprehension of the concept of coherence in quantum theory is fundamental in the construction of quantum optics and is made by means of the definition of correlation functions. In the present work, a parallel between the concept of coherence in quantum and classical theories are made. In particular, the coherence of a quantum an classical Bell state is studied. Taking into account that entanglement is not a purely quantum property, a comparisson of this quantity in both frameworks is made.

Study of the dynamics of optically trapped magnetic particles

Loreto Alejandra Martínez Prieto

(Physics Institute, Pontificia Universidad Católica de Chile)

Optical tweezers are a powerful tool in the study of micro and nano-systems, widely used in biology and medicine. They consists of a non-invasive technique that allows the manipulation of particles using a highly focused laser beam. We specifically study magnetic micro-particles in fluid enviroments using a fully operating optical tweezers system, which allows us to precisaly monitor the dynamics of optically trapped particles.

Accurate determination of energy levels, hyperfine structure constants, lifetimes and dipole polarizabilities of triply ionized tin isotope.

Mandeep Kaur

(Guru Nanak Dev University)

The investigations of energies, magnetic hyperfine structure constants, lifetimes and electric dipole matrix elements of a number of low lying states of triply ionized tin isotope have been carried out using relativistic coupled cluster theory. The contributions from the Breit interaction and lower order quantum electrodynamics (QED) effects in the determination of above quantities are also given explicitly. These higher order relativistic effects are found to be important for accurate evaluation of energies whereas QED effects are seen to be contributing significantly to the determination of magnetic hyperfine structure constants. The calculated electric dipole matrix elements are further utilized to estimate the transition probabilities and dipole polarizabilities of many states. The estimated dipole polarizability values will be useful for carrying out high precision measurements using Sn 3+ ion in future experiments.

Coherent transport of light in ordered and disordered atomic samples

Marcia Frómeta Fernández

(Instituto de Física de São Carlos)

The scattering of light by the diluted matter can be treated as a phenomenon of waves diffusion. The constructive interference of multiple scattering paths generates deviations from the purely diffusive behavior, which accentuate as the average free path is reduced. Below a certain critical value of the mean free path, scalar models of waves diffusion in disordered systems predict the emergence of Anderson's location, or the diffusion suppression, already verified for acoustic and matter waves, and for light only in 1D and 2D diffusion. Recently the existence of the 3D location of waves vector, such as light, has been theoretically questioned, and it is now accepted that it should not happen in the absence of a strong magnetic field because of the presence of short-range terms in the electric field near light which become strong when the density of scattering increases, opening up polarization channels by which light can still diffuse. This work proposes the study of 3D light scattering in the dense regime by an ensemble of cold isotropic atoms, with the objective of experimentally identifying signatures of absence of localization and effective short-range inter-atomic interaction.

Topological materials and their interface electromagnetic properties

Matías Cubillos Cabrera

(Facultad de Fisica, Pontificia Universidad Católica de Chile)

Topological insulators are a category of phases in condensed matter with inverted conduction and valence bands. As a result, the bulk keeps insulating while the surface supports an exotic high-mobility spin-polarized electronic states. Introducing electromagnetic interacions affects the behavior of hall edge states, the characterization of this behavior is an essential step to bring topological insulators towards the observation of new quantum states and for device applications.

Toward a continuous observation of Bloch oscillations of ultracold atoms

Michelle Alejandra Moreno Armijos

(Instituto de Física de São Paulo - USP)

Methods borrowed from atomic interferometry promise great advances in the development of new inertial sensors. One particularly attractive technique translates the gravitational acceleration force into a measurement of the frequency of Bloch oscillations of laser-cooled atoms confined in a vertical stationary light wave. In modern gravimeters, the measurement is destructive and new atomic samples must be prepared for each choice of evolution time. To overcome these destructive measurements, we propose to study a new technique that allows monitoring in vivo Bloch oscillations of strontium atoms. Two key ingredients based on different physical phenomena are needed to implement the continuous monitoring. The first one is the phenomenon of Bloch oscillations. These oscillations, observed in the movement of cooled atoms at temperatures below the photonic recoil limit, placed within a stationary light wave and subjected to an external force, occur at a frequency strictly proportional to the acceleration. The second ingredient is Collective Atomic Recoil Laser (CARL). This effect is observed with cold atoms interacting with two counterpropagating modes of a ring cavity. It is due to the conversion of kinetic energy from atoms used to create a field of laser radiation containing information about atomic motion. The created field serves as a non-destructive and continuous proof of the dynamics of wave-matter and the inertial forces which it is subjected. Optical cooling of strontium is performed in a two step process. So far, the first phase has been implemented and we are working on the second. In the first phase, strontium atoms ejected from a heated oven are decelerated in a two-dimensional magneto-optical trap (2D-MOT) and leaded to a 3D-MOT operated in the strong transition at 461 nm, with 32 MHz line width. When the trap is loaded with sufficient number of atoms, the laser beams of this (blue) MOT are turned off and the second phase starts, which consists of a (red) MOT operated at the narrow intercombination line of 7.6 kHz at 689 nm. Temperatures around 1 μK should be attained. Now, laser beams near the resonance at 689 nm are injected into the two counterpropagating modes of the cavity. They form a standing wave interacting with the atoms. Within this wave the atoms perform Bloch oscillations that can be continuously monitored by beating the light fields leaking from the cavity and superimposed on a photodetector.

A Paul trap for studying the interaction of single ions with structured light

Nicolás Adrián Nuñez Barreto

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In this work we describe the set up and the first experiments of ion trapping in a Paul trap. It uses quadrupolar static and radiofrequency electric fields to confine in space several, or even only one ion. In this work we show the first results of the trap, involving cold trapped crystals of a few calcium ions. In the short term we will study the interaction of ions with structured light beams, in order to develop vectorial beam tomography and coherent spectroscopy.

Localization versus subradiance in three-dimensional scattering of light

Noel Araujo Moreira

(Instituto de Física de São Carlos)

We study the scattering modes of a light in a three-dimensional disordered medium, above the critical density for Anderson localization. Contrary to the usual conductor-insulator transition picture, localized modes represent a minority of modes, even well above the threshold density, whereas spatially extended subradiant modes predominate. Even an appropriate choice of the probe frequency does not allow to address localized modes only. The lifetime of localized modes is shown to be dominated by finite-size effects, and more specifically by the ratio of the localization length to their distance to the system boundaries.

Collisional model-based quantum heat engines

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In the context of quantum thermodynamics, the study of quantum heat engines is of utmost importance. A recent and interesting approach is to study such engines in the framework of repeated interactions (collisional models), where each environment is made of an ensemble of identically prepared auxiliary systems, which interact sequentially with an individual subsystem for an infinitely small time, giving birth to a local master equation (LME), for whatever internal interactions the subsystem might have. In this work we show a system made of two environments (cold and hot baths) and a subsystem that interacts with these environments that can be either fermionic (qubits) or bosonic (quantum harmonic oscillators). Applying the above mentioned method, we arrive at general expressions of the heat rate exchanged between the subsystem and the baths, and also of the work rate exchanged with the outside world, which stems from the internal interactions of the subsystem. Such expressions show that the system can operate in different regimes: refrigerator, engine and accelerator (i.e. an oven). Finally, these regimes are explored for different internal interactions of the subsystem, in search of possible advantages on, for example, output work and/or efficiency for the engine regime, for example.

Probing Mollow's triplet with scattered light by cold atoms.

Pablo Gabriel Santos Dias

(Physics Departamente - Federal University of São Carlos)

The purpose of this work is the observation of Mollow's triplet with cold atoms. This triplet is the spectrum of light scattered by strongly driven atoms, which has the typical shape of three peaks separated by the Rabi frequency. In this work, we propose a new scheme to observe the Mollow's triplets, based on the interference of light scattered by a cold cloud of atoms and their mirror images. The cloud used to probe the signal is produced using magneto-optical traps (MOT) on two transitions of 88Sr. First, we use a MOT on a broad transition at 460.8 nm with 30.5 MHz of linewidth, and then, we transfer this cloud to a MOT on a narrow transition at 689 nm with 7.6 KHz of linewidth. This second stage allows us to produce a thin cloud which is fundamental to probe the Mollow's triplet. The interferometer-like setup is built using two lenses and a mirror. It creates a standing wave at the cloud position, which excites the atoms and afterward produces a beat note of the light scattered by the could in two opposite directions. Using a lens we collected the light scattered and expect to observe fringes when looking at light scattered around the angle of incidence. These fringes have an angular gaussian distribution with the number of fringes inversely proportional to the width of the cloud. We already observe this fringes in the low-intensity regime with the first stage of cooling, as reported in [1]. Now, using the second stage of cooling, which was implemented last year, we are able to produce a cloud with 200 \mu m x 500 \mu m. With this cloud, we will probe an oscillation of fringes contrast as predicted in [2], due to the beating of Mollow's sidebands in the high-intensity regime. Until now, we aligned all the optics to excite and to collect the emitted light. We did a scan for different angles searching a better region to collect the light and we found a good region to collect light with low noise. Now, we are trying to find the first signal of the fringes in the low saturation regime, to then switch to the strongly driven regime. Because it is a simple setup, this platform can be very powerful to study the light scattered by highly-driven systems.

Techniques of Optical Trapping Through Generalized Phase Contrast (GPC)

Pedro Faleiros Silva

(Instituto de Física de São Carlos)

The motivation of this project is to develop experimental techniques of optical trapping and optical control applicable to atomic physics and nanotweezers as a platform to study important contemporary problems of modern physics and technology - which is in the context of the generation of arbitrary optical potentials to simulate out-of-equilibrium systems, coherent control of qubits, and quantum simulation. In particular, in this project has been studied the spatial modulation of light by the Generalized Phase Contrast (GPC) technique, to produce with high precision different optical potentials. Unlike the more well-known technique of holography, the GPC can produce very sharp potentials without speckles and that allows a single pixel control through a single path interferometer (1). Basically, the GPC works creating a phase-shift in the zero spatial frequency components of the laser beam modulated in a Spatial Light Modulator (SLM) and building a interferogram through a 4f optical correlator (1,2). In this context, will be shown our first results with a preliminary technique of GPC, known as Zeroth-Order technique, wich has the same optical system and works creatting a high precision amplitude mask through phase control of the light (2). In both cases our main goals include the comparison of this techniques with holography, build an automated system for the potentials control and make a quantitative study of GPC and its derivations for optical trapping.

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Magnetic field dependence on the the fluorescence of Nitrogen-Vacancy center in diamond.

Raul Manuel Gonzalez Brouwer

(Pontificia Universidad Catolica de Chile)

In this work, we study the hyperfine interaction between a nuclear spin 1=2 and electron spin 1 in the crystal lattice of a diamond at room temperature. The electron spin is generated by the presence of nitrogen-vacancy defect center (NV) and nuclear spins are products of nearby carbon isotopes 13C and nitrogen 15N. We are interested in studying the couplings that arise from the hyperfine interaction between the spins, for this it’s necessary to apply an external magnetic field in the direction of the quantization axis of the NV center (NV axis), the Zeeman effect approximates the energy of a polar level of the electronic spin (ms = ±1) to the neutral level energy (ms = 0), so that the energy differences are close to the coupling energies. This situation occurs in the vicinity of what is known as the anti-crossing level of the NV center and allows us to make an important approximation, which corresponds to consider only the two closest levels of the electronic triplet.

Quantum sensing with Rydberg atoms

Rémi Richaud

(Laboratoire Kastler Brossel)

Rydberg atoms are highly excited states of an atom, in which the electron is located far from the nucleus. These states exhibit enhanced properties such as large electric or magnetic dipoles, making them very sensitive to their electro- magnetic environnement and thus good candidates for quantum metrology. Using microwave and radio-frequency fi elds, our team is able to engineer the quantum state of the atoms to probe electric and magnetic fields with a sensitivity below Standard Quantum Limit (SQL). The measurement is performed using Ramsey interferometry involving states with very different dipoles. We prepare the atom in a superposition of states with different sensitivity to the field. Measuring the quantum phase between the two states allows us to probe the varations of the eld. We fi rst use the Rydberg atom to detect small variations of electric field, and reach a sensitivity of 0.3 mV/cm for a 200 ns interrogation time. For shorter interrogation time, the single-atom sensitivity is -14.8dB below the SQL. This electrometric technique could have applications for detection of individual charged particles in mesoscopic physics. We then performed a magnetic fi eld measurement using a quantum superposition of two opposite angular momentum circular states. This non-classical state corresponds to an electron rotating in two differrent directions on the same circular orbit, with a dipole difference of the order of 100 Bohr magneton. This single-atom magnetic probe is able to perform a detection of 13 nT fi eld in 20µs. The experimental results are limited by the anharmonicity of the rubidium energy stucture. We have implemented, in collaboration with the university of Kassel, optimal control algorithms to improve the preparation and readout efficiencies of atomic states, thus leading to even better sensitivities.

Single Molecule Magnets for Spintronics and Quantum Information

Richard Escalante de Posada

(Universidad Catolica de Chile)

We are investigating single molecule magnets to see if we can manipulate and detect their spin by monitoring their luminescence. This is similar to the nitrogen vacancy center defect in diamond, however we would like to find a single molecule which exhibits this behavior. The other avenue of work we would like to do is use the NV center as a means of detecting molecules which do not exhibit this spin dependent luminescence. This would be done by measuring the relaxation rate of the NV in the presence of these molecules while under an externally applied magnetic field. This relaxation would increase when the energy transitions in the molecule and NV are on resonance from the Zeeman splitting.

Study of Photons Correlations in Stokes-anti-Stokes Process Using an Effective Hamiltonian

Róbinson José Acosta Diaz

(Instituto de Fisica - Universidade Federal do Rio de Janeiro)

The scattering of light by matter exhibits two components, the Stokes and the anti-Stokes events. The former turn out when an incident photon is converted into a phonon and a redshifted photon, and the other when one incident photon and one existing phonon are annihilated, generating a blueshifted anti-Stokes photon. A joint process is also possible, i.e. a correlated Stokes-anti-Stokes event, where a photon created by the Stokes process is subsequently annihilated in the anti-Stokes process, given rise to correlations between the created photon-pair. Experimentally, evidence for the Stokes-anti-Stokes process and its quantum nature has been presented in the literature for different materials. In this scenario, our aim is to study the correlation of these kind of photon-pairs created by the action of short pulses of lasers, and also the scattering properties considering an effective Hamiltonian that includes correlation between the Stokes and anti-Stokes events.

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Róbinson José Acosta-Díaz

(UFRJ)

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Statistical properties of light of two interacting cavities with embedded nonlinear media

Santiago Bermúdez Feijóo

(Universidad Nacional de Colombia - Sede Bogotá)

Single photon sources are a substantial requirement for the upcoming quantum revolutions. In this work, the study of two linearly interacting cavities with a nonlinear Kerr media embedded constitute a suitable experimental proposal for achieving low statistics. The optimal parameters in with single photons are produced are found.

Quantum Darwinism: Correlations and Non-Markovianity

Sheilla de Oliveira Marques

(Universidade Federal de Minas Gerais - ICEx)

In order to explain aspects of the quantum-to-classical transition, quantum Darwinism (QD) explores the fact that, due to interactions between a quantum open system and its surrounding environment, information about the system can be spread redundantly to the environment. Here will present a finished work about QD and non-Markovinity (NM) in a quantum harmonic oscillator system and some results about the current work where we are studying QD in a two-level atom inserted in a fermionic environment. In the first work, we point out how to detect QD in two distinct and non-equivalent way. We then consider a model where Darwinism can be seen from both perspectives. Moreover, the NM of our model can be varied with a parameter. Departing from the analysis of a recent study about QD and NM we argue that, from both perspectives to quantum Darwinism, there is no clear relationship between non-Markovianity and quantum Darwinism in our model. In the second work, we could see some evidence that strong intra-environmental correlations present in some fermionic systems can make affect the observation of QD.

Optical trapping of microparticles and development ofdynamic optical potentials

Thalyta Tavares Martins

(Instituto de Física de São Carlos)

From the development of motion control and particle positioning methods using lasers in the early 1970s to the recognition with the 2018 Nobel Prize for Physics, one of the most versatile optical manipulation tools, so-called tweezers have been used mainly to explore objects in two size regimes: the limit of the sub-nanometric particles (atoms and simple molecules), and the limit of the micrometric particles. In this context, a new experimental apparatus was developed and built to trap micro and nanoparticles in an optical tweezers. Calibration was performed using the energy equipartition method and optical potential analyses resulting in a trapping force of the order of piconewtons per micrometer. Among the differentials of the optical tweezers built is the ability to design optical potentials that can be controlled dynamically, using an acousto-optic modulator. In addition, computational simulations were performed with the purpose of comparing the experimental results with those predicted theoretically and guiding future studies.

Rydberd atoms with low angular momentun in electrodynamic traps

UlisesAlejandro Lopez

(Departamento de Física, FCEyN, Universidad de Buenos Aires)

We present the advances in the development of a radio-frequency trap for neutral atoms. As neutral atoms couple to the electric field as a dipole, we studied the trajectories of the ultra cold atoms in different oscillating electric fields geometries and calculated polarizability for Cesium atoms in Rydberg states with low angular momentum states. We found parameters where the atoms are trapped in our trap geometry and hope to implement this electrodynamic trap in the near future.

Nitrogen-Vacancy Center: A chemical reaction sensor based on Quantum Coherence.

Vicente Andres Santibañez Cisternas

(Pontificia Universidad Catolica de Chile)

Nitrogen-Vacancy Center is a point defect present on diamond which consists of a Nitrogen atom near to a vacancy in the Carbon lattice. This defect has a spin degree of freedom that can be easily manipulated alternating laser and microwave pulses at room temperature. The emitted photons by fluorescence are detected with an APD. After running different pulse sequences like Electronic Spin Resonance (ESR or EPR), Rabi oscillations and Ramsey Interferometry, Coherence Time (T2) can be determined. Based on Jamonneau et al. ("Competition between electric field and magnetic field noise in the decoherence of a single spin in diamond", 2016), Coherence Time of Shallow Nitrogen-Vacancy Centers is affected, in a particular regime of magnetic field, by external electronic noise. Based on that, we develop a chemical reaction sensor for aqueous solutions with nanometric resolution. More details will come in my poster.

Long-range interactions in the Scalar Pseudo-QED

Ygor Pará Silva

(Programa de Pós-Graduação em Física (PPGF-UFRN))

The Pseudo-Quantum Electrodynamics (PQED) provides an excellent description of the interaction between charged particles confined in a plane. When we do the coupling of the PQED with a bosonic field of matter, we obtain the so-called Scalar Pseudo-Quantum Electrodynamics (SPQED). In this work, we make a perturbative analysis of SPQED via Feynman diagrams. We compute the one loop Green functions: bosonic field self-energy, electromagnetic field self-energy, and vertex corrections. After this, we analyze the emergence of long-range interaction potentials in the static limit. This approach can be useful to study superconductivity phenomena and ultra-cold atomic systems in mixed dimensionality.