Probing topological phase transitions in the graphene family via quantum reflection

Patrícia Abrantes

Quantum reflection (QR) consists in the reflection of incident quantum particles under the influence of a potential that decreases monotonically in the direction of the particle motion, despite the absence of any turning points. It finds applications in the design of atomic mirrors and atomic traps, as well as in the study of interactions involving Bose-Einstein condensates and high-precision measurements of the short-range regime of gravitational forces. Therefore, developing alternative mechanisms to tune the QR probability of an atomic beam is of great interest. A possible approach to achieve this control is to take advantage of QR's strong depen- dency on the Casimir-Polder interaction between incident particles and a given reflecting wall – which may be substantially altered by changing the wall's material properties and the particles. In this work [1], we investigate the QR of different atomic species by graphene family ma-terials. Several topological phase transitions are induced due to the application of an external electric field and by irradiating circularly polarized light in the 2D sheets. We show that the QR probability can be significantly modified by varying the intensities of these external agents. Our results also indicate that the topological phase transitions leave a characteristic signature on the QR probability, suggesting that QR could be used as an alternative optical method to probe such transitions experimentally.

Photon's pairs properties generated by spontaneous parametric down-conversion in crystals pumped by vector beams.

Matheus Aleluia

The generation of photon pairs by spontaneous parametric down-conversion in nonlinear crystals is a well-known phenomenon and has been intensely stu- died in the PD-UFMG quantum optics group. In general, studies are focused on crystal pumping schemes by uniformly polarized laser beams. Many re- sults have already been obtained with the use of pumping beams with more complex transverse profiles, including those with orbital angular momentum. Another class of electromagnetic beams has been much studied in recent years. These are the so-called vector beams, in which the state of polariza- tion varies with the position in the normal plane to the propagation direction. Most common examples of these beams are those with radial polarization, and those with azimutal polarization. The application of vector beams in ge- nerating twin photons for spontaneous parametric down-conversion has not yet been explored. In this work, the transverse correlation properties of pho- tons generated by the pumping of nonlinear crystals by vector bundles will be studied from both the theoretical and experimental point of view.

Probing the spatial and temporal decay of quasimodes in open Vogel spirals via localization maps

Marcus Vinícius Alves

We investigate the temporal and spatial properties of the quasimodes of open Vogel spiral planar arrays. The analysis of the localization maps reveals that optical quasimodes with three types of spatial decay coexist in these deterministic aperiodic structures: exponential, Gaussian and power-law decay. On average, the Gaussian ones are found to be the most spatially and temporally localized. In addition, our results provide the first direct demonstration of critical quasimodes in Vogel spirals.

New regimes in cavity QED with trapped ions

Cesar Amaral

Ions trapped inside optical cavities are used to study many phenomena in quantum physics, such as the entanglement between ions and photons, as well as the generation and detection of quantum states. This system has also been used as a quantum network node, which is essential in quantum computing and secure communication through these technologies. In a strong coupling regime, where g is comparable to the other frequencies of the system, it is possible to produce highly efficient single-photon sources and high-fidelity ion-photon quantum interfaces, which are key components in quantum networks and quantum computing. While this regime brings advantages, it also brings new challenges, since the theoretical works published on this subject usually use weak coupling to apply the famous rotating wave approximation (RWA) and obtain effective Hamiltonians. Furthermore, some works present the inclusion of a photon detector outside the cavity, and it has already been shown that the detection of a photon can influence the non-classical aspects of the state inside the cavity. Thus, an attempt to obtain an effective Hamiltonian for the problem of a single two-level ion trapped in a Paul trap and placed in an optical cavity, using a unitary transformation, was carried out. Additionally, results are presented on how a detector placed outside the cavity influences the quantum aspects of a state over time, using quantifiers of non-classicality.

SPATIAL COHERENCE MAP OF SPINS USING NV CENTERS IN DIAMONDS

Lucas Andrade

The nitrogen-vacancy (NV) center in diamond is an excellent solid-state spin system for quantum sensors due to its electronic spin properties. Its triplet ground state is easy to manipulate (using lasers and microwaves) and to optically initialize/readout at room temperature. Several works reported its use as a sensor for temperature, strain, electric fields, and mainly a sensor of magnetic fields. This work brings another use of the NV centers, using an engineered sample of ultra-pure diamond and a home-built imaging protocol, with a simple CCD camera, to reconstruct the spin coherence map of a 2D quantum sensor, using a quantum measurement protocol.

Decoding Black Hole Quantum Phenomena: Correspondences with quantum optics processes

Adriano Braga Barreto

In this poster, we highlight the similarities between the optical and gravitational amplification of vacuum fluctuations in the electromagnetic field. Specifically, we discuss the correspondence between the well-known process of spontaneous parametric down-conversion, a second-order nonlinear-optical process, and the spontaneous emission of thermal radiation by a non-charged and non-rotating black hole, known as Hawking radiation. This correspondence reveals a mathematical connection between seemingly unrelated phenomena and sheds light on the nature of both processes. Recognizing this mapping could provide a more intuitive understanding of this semiclassical gravitational effect and can serve as a platform to simulate it in table-top experiments.

From classical to quantum loss of light coherence

Mateus Biscassi

Light is a precious tool to probe matter, as it captures microscopic and macroscopic information on the system. We here report on the transition from a thermal (classical) to a spontaneous emission (quantum) mechanism for the loss of light coherence from a macroscopic atomic cloud [1]. The coherence is probed by intensity-intensity correlation measurements realized on the light scattered by the atomic sample [2,3], and the transition is explored by tuning the balance between thermal coherence loss and spontaneous emission via the pump strength. Numerical simulations are realized in parallel with the experimental measurements , which allow to identify the critical role of the low temperature in the observation of the transition. Furthermore, the simultaneous measurement of the field-field correlations allows us to verify that the Siegert relation is valid for both regimes [4,5]. The Siegert relation establishes an equivalence between the (loss of) coherence for the field and for the intensity, thus, we can conclude that the field does not suffer extra loss of coherence compared to the intensity. Our results illustrate the potential of cold atom setups to investigate the classical-to-quantum transition in macroscopic systems.

Thermometry in ion crystals

Muriel Bonetto

The high degree of control that trapped ion platforms offer can be exploited to simulate quantum and classical systems. One area of particular interest is the study of transport phenomena in the vibrational degrees of freedom of an ion crystal, which requires estimating the local temperature of the crystals. In this work we present our advances in single ion thermometry in a Paul trap. We implement two methods to estimate the ion temperature: Doppler broadening and CPT spectroscopy, and study the effects excess micromotion has in these experiments.

Enhanced Control in NMR-Based Quantum Computing

Gustavo Café

Quantum computing has the potential to revolutionize many areas of science and technology, and Nuclear Magnetic Resonance (NMR) is one of the earliest and well-established methods for quantum computing systems. Controlling NMR qubits, however, presents significant challenges, requiring the development of sophisticated algorithms.

Former algorithms such as gradient ascent pulse engineering (GRAPE) have shown weaknesses when dealing with fine control necessary for computation. In this work we have built on novel deterministic approaches to pulse shaping, using Peterson and Laflammes algorithm based on Nelder-Mead optimization. By means of applying Machine Learning techniques to the optimization stage, we aim to further improve control, in order to reduce computational time and generalize to noisier qubits.

Optimization of a multi-step control scheme for the vibrational stabilization of diatomic molecules

Mateo Londoño Castellanos

In recent decades, considerable experimental and theoretical efforts have been dedicated to the formation of diatomic molecules from cold ($1\ \mathrm{mK}<T<1\ \mathrm{K}$) and ultracold ($T<1\ \mathrm{mK}$) gases, as this is a fundamental problem in chemistry, physics and astrophysics [1]. Promising methods for this task are magnetoassociation and photoassociation, followed by a rovibrational stabilization scheme that can lead the molecule to its absolute ground state [2]. We propose a three-step methodology, consisting of an intracurve ladder descending scheme followed by a pump-dump scheme. We implement computationally the first scheme for a KRb molecule, which is initially trapped in a Feshbach resonance of the first triplet state. We optimize the laser pulse by means of a genetic algorithm [3].

Optical characterization of defects in hexagonal boron nitride monolayers

Nicolás Vera Castillo

Artificial atomic systems in solids are the leading physical system for use in quantum technologies. One of the most prominent systems used are wide band gap semiconductors such as nitrogen vacancy centres in diamond, due to its large coherence times even at room temperature. Another system that has been shown to generate single photon emission are van der Waals crystals such as hexagonal Boron Nitride (hBN). However, single photon emission from colour centres in two dimensional hBN has been reported primarily at the bulk level. Our goal is to study implanted defects in monolayers of hBN at room temperature for potential applications in quantum sensing and quantum information processing.

Saturation-induced Bistability in Strontium Atoms interaction with an optical cavity

Gustavo Henrique de França

We study the interaction between a cloud of ultracold strontium atoms and the light modes of an optical ring cavity laser-pumped near a forbidden atomic transition. In our cavity 0.1 photons are enough to saturate the narrow transition, which enables us to study saturation-induced effects even on resonance without being hampered by spontaneous emission. Furthermore, with the cavity decay rate exceeding by far the rate of spontaneous emission, we are in the so-called 'bad cavity' limit. The number of interacting atoms is sufficiently high to reach the strong collective coupling regime, where the energy exchange exceeds the energy loss rate, resulting in a characteristic normal-mode splitting of the cavity transmission spectrum. When the cavity was pumped sufficiently strong, however, our measured transmission spectra revealed the presence of a third peak near the atomic resonance, which has not been observed before. We were able to explain this peak as being due to saturation-induced bistability caused by a nonlinear interaction between the Autler-Townes effect and normal-mode splitting.

Scattering Quantum Walks in Planar Hexagonal Dirac Materials: The Parametrization of the SU(3) Approach

Henrique Ghizoni

The Scattering Quantum Walk (SQW) is the quantum analog of a random walk using scattering theory. Quantum walks have been studied and applied in various fields such as quantum computing and information, nonlinear optics, search algorithms, astrophysics, and more. However, most of the literature on QWs focuses on walks occurring in position space, while there are also quantum walks that can occur in momentum space. The last one has proven to be a powerful tool for studying various areas of physics, such as Bose-Einstein condensates, nonlinear optical phenomena, meteorological phenomena, quantum computing implementation, condensed matter physics, and more. With this in mind, we investigated the importance of the scattering matrix for obtaining the band structures of the planar Dirac materials with a planar hexagonal lattice, such as graphene, silicene, and germanene. Our results show that with the proper choice of a scattering matrix, generated by the parameterized SU(3) approach, we can obtain pi and pi* band structures that are very close to those obtained via ab initio methods such as DFT and GGA-PBE, and exactly the same as those obtained via tight-binding nearest neighbors. Furthermore, we demonstrated that it is possible to obtain Fermi velocity relations that converge with the literature in this area for these materials. Finally, we hope to show that the proposed model in this study is a powerful tool for investigating areas related to quantum physics.

Complex vector light fields propagation in atomic systems.

Robert Paul Guzman

Complex vector fields are light states where the polarization pattern is in-homogeneously distributed across the spatial mode. Preparation of these states is possible thanks to the use of geometric and dynamic phase as well spin–orbit effects of light fields. In this work we explore some aspects of the propagation of complex vector light states through atomic systems. In particular we are interested in how the light-matter interactions affect the topological charge of the light states.

Four-wave mixing with Hermite-Gauss modes in Rubidium vapor

Pedro Henrique

In this work, we present experimental results of a degenerate four-wave mixing process in Rb vapor using Hermite-Gauss modes of light. We mainly explore the spatial structure of the nonlinear field in a thin medium regime. In this case, the generated field consists of a combination of various modes. However, the far field appears to be dominated by one specific mode, conditioned to the conservation of mode orders of the incident fields. We measure the spatial profile for two nonlinear signals generated at 2kA-kB and 2kB-kA directions, where kA and kB are the wavevectors of the incident beams. Our experimental data, for a combination of selected modes, showed a good agreement with theoretical results, obtained through the overlapping integral of the incident fields. We're also interested to investigate the thick medium regime, which presents some difficulties to be overcome. In particular, those imposed by the selection rules related to the Gouy phase.

The longitudinal component of the Casimir interaction between spheres

Larissa Inacio

In this work, we investigate the dispersive interactions between two spheres immersed in an electrolyte solution. We begin by solving the Mie scattering problem for two homogeneous spheres immersed in a 1:1 electrolyte by focusing on the contribution of the longitudinal modes. Since ionized solutions typically have a plasma frequency much smaller than $k_BT/\hbar$ at room temperature, only the contribution of the zeroth Matsubara frequency is affected by the screening caused by electrolyte ions. However, due to the fact that the ions make the permittivity of the solution nonlocal, longitudinal modes in the bulk are allowed. Such modes complicate the electromagnetic scattering problem, not only due to the extra boundary conditions but also because they make the scattering matrix larger (i.e., with more independent entries). Finally, by adapting the scattering formalism typically used in Casimir force calculations, we determine the expression for the generic force between two arbitrary spheres and the contribution of the longitudinal component to the Casimir force. Our result is compared with previous work for the limit for an interaction of small spheres.

The Wave Functions of the Photon

Joás Jardim

The photon wave function formalism, definitively established in the 1990s, has been successfully used in cases of light propagation in turbulent media and in the interaction of radiation with matter. In the nanospectroscopy group at DF-UFMG, the photon wave function formalism based on the Riemann-Silberstein vector has been successfully used to describe the generation of pairs of photons by Raman scattering. In addition to the Riemann-Silberstein vector, the potential vector can be used as the basis for a photon wave function. This formalism is especially suitable for the study of the quantization of non-propagating electromagnetic waves, also known as evanescent waves, very common in problems of interaction of electromagnetic waves with material media. The main objective of this work is to present the formalism of the photon wave function using the Riemann-Silbertein vector and to emphasize the use of the potential vector as a basis for future studies of the near-field regime of the interaction of radiation with material media.

Source of Polarization Squeezed States - Single Passage Through a Kerr Medium

Eduardo Lima

The generation of squeezed light can be described by the non-linear interaction of a coherent light with a medium that has $\chi^{(n)}$ non-linear susceptibility. A special case is the polarization squeezed light, generated by $\chi^{(3)}$ non-linear interactions. Here we present a way of creating a squeezed state via single passage through a Kerr medium and the ongoing work of the sidebands description of the polarization squeezed light.

Insulator Phases of Bose-Fermi mixtures induced by next-neighbor interactions between fermions

Felipe Gomez Lozada

We consider the effect of next-neighbor interactions between fermions on the ground state of a one-dimensional mixture of scalar bosons and two-color fermions. Exploring the parameters of the problem, we obtained the emergence of three new insulating states, which consists of an immiscible charge density wave at half-filling of bosons and two insulators, one of them a spin selective phase, that appear when the bosonic density is equal to a fermionic density. In order to shed a light on these states, we show a phase diagram for the possible configurations in which the novel insulators can appear, along with certain characteristics of them.

Implementation of an optical accordion for bosonic strontium atoms

Matheus do Amaral Martins

Theoretical studies show that changes in the lifetime of the elementary excitations of the lattice are simple functions of its geometry, and give rise to efficient storage protocols and coherent production of single photons. This work aims to implement an optical accordion, which is an intermediate step to obtain an optical lattice in a system of ultra-cold strontium atoms in the future, which will be used to study these effects.

Quantum Vacuum Sagnac Effect

Guilherme Costa Matos

We report on the quantum electrodynamical analog of a Sagnac phase induced by the fast rotation of a neutral nanoparticle onto atomic waves propagating in its vicinity. The quantum vacuum Sagnac phase is a geometric Berry phase proportional to the angular velocity of rotation. The persistence of a noninertial effect into the inertial frame is also analogous to the Aharonov-Bohm effect. Here, a rotation confined to a restricted domain of space gives rise to an atomic phase even though the interferometer is at rest with respect to an inertial frame. By taking advantage of a plasmon resonance, we show that the magnitude of the induced phase can be close to the sensitivity limit of state of the art interferometers. The quantum vacuum Sagnac atomic phase is a geometric footprint of a dynamical Casimir-like effect.

Four-mode Entanglement Out of Two Beams: the Four-Wave Mixing Case

Théo L. Meireles

Parametric processes, such as those occurring in optical parametric oscillators (OPO's) and optical parametric amplifiers (OPA's), are widely known and studied for their ability to produce non-classical states of light using non-linear materials. Furthermore, properties such as entangle- ment that can be generated in those systems are essential for developing quantum technologies such as quantum computing. To implement a resourceful quantum system to process or share information (a quantum network) a significant number of entangled modes with atoms being the nodes and entanglement the channels need to be produced [1]. With that in mind, we developed an optical parametric amplifier with a Rubidium (Rb85) vapor cell as the non-linear medium, capable of producing, through the four-wave mixing process (FWM), a pair of intense beams, probe and conjugate, from the annihilation of photons of the pump beam. Previous works [2] show theoretically and experimentally that these beams of light should have the quadratures of their electromagnetic fields entangled, showing that this is a bipartite system. In order to reveal a more complex structure, we studied the correlations that would exist between the upper and lower side-bands of the probe and conjugated beams. To do this, we use the cavity-assisted measurement technique [3] so that we can completely reconstruct the covariance matrix for the state, distinguishing the side-bands. By doing this we show a quadri- partite structure of entanglement between the side-bands even with only two beams in addition to the asymmetry effects that arise due to the gain profile of the OPA.

Enhancing exotic quantum fluctuations in strongly entangled cavity-BEC systems

Leon Mixa

Cavity-BEC systems with strong coupling between the atomic and cavity sector provide extraordinary possibilities for observing details in their Dicke phase transition through the cavity loss channel. By microscopic derivation starting from the systems field Hamiltonian, we uncover the atomic quantum fluctuations around the condensate. These quantum fluctuations are then captured in exact fashion as the bath of a system-bath description of the cavity-BEC. We find analytic expressions of the spectral densities governing the Landau and Beliaev damping. This enables unprecedented insight as we investigate their influence on the strongly entangled system.

We discuss in detail, how to control the faceted bath in particular concerning the sub-ohmic quantum fluctuations. Furthermore, we present the influence on the system and its Dicke phase transition with regard to the critical point, universality class and temperature dependence. This also allows us to discuss the experimental accessibility of the quantum fluctuations.

Dipolar Bose-Einstein condensates in a bubble trap.

Ossamy Okura

Since 1911 when Heike Kamerlingh Onnes discovered superconductivity in solid mercury,the physics of low temperatures has been developing and having more and more progress in the techniques of production and control of matter. In this scenario, scientists in partnership with the International Space Station (ISS) created a Bose-Einstein Condensate (BEC) on theISS, a microgravity environment, which allows experiments in microgravity. Furthermore, an important characteristic of BECs is that they can present, in addition to the contact interaction,which is short-range and isotropic, the dipole-dipole interaction, which is long-range and anisotropic. In this work, we intend to study the ground state and collective excitations of a dipolar BEC in a bubble trap.

Quantum many body dynamics in ultracold gas mixture in structured light created using MEMS device

Gourab Pal

There is a tremendous interest in trapping, storing and manipulating quantum gas in micro and nano-kelvin temperatures in optical traps which are robust, straightforward to create, and also fully reconfigurable. These systems are among the most promising hardwares to study the dynamics of quantum many- body physics. In our lab, we create fully reconfigurable optical potentials to trap the ultra-cold quantum degenerate mixtures to study various exotic quantum phenomena. A Micro-Electro-mechanical system (MEMS) based digital micromirror device (DMD) where we spatially modulate the light beam amplitude is used to create such painted potential. The response of DMD being very fast (12kHz refresh rate), we can track the atom dynamic in microsecond time-scale, eventually leading to dynamical study without significant heating of atoms. In our lab, we have a two-species mass and spin imbalanced Sodium-Potassium cold atom system to produce the quantum degenerate mixtures. Future goal is to trap the condensate in engineered micro-traps and to study the trapped atoms adapting to changes in such potential landscapes. This will aid in studying various quantum many-body correlations helping in identifying exotic quantum phases. In this poster, I present the performance of our newly built two species cold atom trap, as well as the implementation of designer optical potential using the DMD. I shall also present our newly implemented method of principal component analysis (PCA) based image processing to record signals from our cold atoms with a very high signal to noise ratio. We report the light assisted interspecies cold collisions between heteronuclear atoms. Also, recently we have produced the structure in the probe light beam to impact the orbital angular momentum (OAM) to the cold atoms. The idea is to store the OAM from photons to cold atoms and then manipulate after a variable storage time. This will be helpful for storing quantum information in cold atoms with high ($l>2$) OAM.

Effective potentials in a rotating spin-orbit-coupled spin-1 spinor condensate

Paramjeet

An important research direction opened up in the field of quantum degenerate gases with the experimental realization of artificial gauge fields [1, 2] and spin-orbit (SO) coupling between the spin and the linear momentum of electrically neutral bosons [3]. We theoretically study the stationary-state vortex lattice configurations of rotating spin-orbit- and coherently-coupled spin-1 Bose-Einstein condensates (BECs) in quasi-two-dimensional harmonic potentials. We explore the combined effects of rotation, spin-orbit, and coherent couplings on the spinor system from the single-particle perspective, which is exactly solvable for one-dimensional coupling, under specific coupling and rotation strengths. We illustrate that a boson in these rotating spin-orbit-coupled condensates is subjected to effective toroidal, symmetric double-well, or asymmetric double-well potentials. In the presence of mean-field interactions, using the coupled Gross-Pitaevskii formalism at moderate to high rotationfrequencies, the analytically obtained effective potential minima and the numerically obtained coarse-grained density maxima position are in excellent agreement. The effects of rotation are further elucidated by computing the spin expectation per particle for the ferro- and the antiferromagnetic BECs.

Inertial Quantum Sensing with Strontium Atom

Claudio Alves Pessoa

This work focuses on phenomena of light-matter interaction shaped by the presence of an optical ring cavity with applications in quantum sensing. We constructed an experiment to cool down clouds of strontium atoms to ultralow temperatures close to the single photon recoil limit and store them in the dipolar potential formed by a mode of the ring cavity laser-pumped far from a narrow atomic transition. Cavity transmission spectra exhibit a splitting of the normal modes of the atom-cavity system, which proves that we are in the strong collective regime. Currently, we are setting up a high-sensitivity matter-wave interferometer using ultracold atomic clouds for inertial sensing and gravimetry pursuing two alternative routes: a- Using a Ramsey-Bordé pulse sequence we will split and recombine strontium matter waves in a Mach-Zehnder type interferometer. The phase of the interference fringes is very sensitive to the presence of external forces. b- Observing Bloch oscillations performed by ultra-cold strontium atoms inside a periodic optical lattice formed by two counterpropagating modes of the ring cavity. The periodicity of the Bloch oscillations is strictly proportional to external forces.

Bose-Einstein condensates in bubble traps

Clarissa Pinheiro

The study of Bose-Einstein condensates (CBEs) in a bubble trap is a topic of modern research that aims to understand the behavior of boson gases in conditions of absence of gravity and extremely low temperatures. Recently, there have been significant advances in the production and manipulation of CBEs in the laboratory and even in spacecraft orbiting the Earth, allowing for the use of spherical bubble traps to confine atoms in regions of microgravity. In this work, we intend to study variationally the properties of condensates in bubble traps. We will seek to investigate both static properties, such as the distribution of particles in space, and dynamic ones, such as low-energy excitations.

Optimal time-entropy bounds and speed limits for Brownian thermal shortcuts

Luís Pires

By controlling in real-time the variance of the radiation pressure exerted on an optically trapped microsphere, we engineer temperature protocols that shortcut thermal relaxation when transferring the microsphere from one thermal equilibrium state to another. We identify the entropic footprint of such accelerated transfers and derive optimal temperature protocols that either minimize the production of entropy for a given transfer duration or accelerate as much as possible the transfer for a given entropic cost. Optimizing the trade-off yields time entropy bounds that put speed limits on thermalization schemes. We further show how optimization expands the possibilities for accelerating Brownian thermalization down to its fundamental limits. Our approach paves the way for the design of optimized, finite-time thermodynamic cycles at the mesoscale. It also offers a platform for investigating fundamental connections between information geometry and finite-time processes.

Reducing phase noise of on-chip optical parametric oscillators

Gabriel Couto Rickli

We have recently measured the states of light generated by an above-threshold optical parametric oscillator integrated on a silicon nitride chip. We observed 2.30(3) dB of difference of amplitudes squeezing, and excess noise in other combinations of quadratures. The excess noise hinders the observation of entanglement in the system. We postulate that the extra noise is due to thermorefractive (phonon) noise, and propose an experiment to investigate the origin of this noise.

Stability of a Bose-Einstein condensate mixture on a bubble trap

Leonardo Brito da Silva

Bose-Einstein condensates (BEC) confined in spherical geometries are currently feasible with the achievement of bubble trap confinements in cold atom experiments performed in microgravity

conditions aboard the International Space Station. We simulate this system by a perfect spherical two-dimensional shell surface and study analytically and numerically the dynamic stability of BEC binary-mixture systems, taking into account the intra- and interspecies interaction effect on different initial conditions. We perform our studies by observing Bogoliubov de-Gennes (BdG) spectrum and the dynamics simulation driven by the Gross-Pitaveskii (GP) equation.

Potencial and Feshbach s-wave resonances in coupled atomic collision channels

Grover David Andrade Sanchez

With a stylized model we study two-channel binary collisions of identical atoms, common in current ultracold gases experiments. Those channels represent two internal hyperfine states whose energy separation can be tuned by means of an external magnetic field. The scattering occurs for energies, such that one channel appears closed and another open, in the asymptotic region. We show that there are two types of resonances, one due to the appearance of a bound state of the full coupled system (potential resonance), where the scattering length diverges, and another that occurs when the incident energy is closed to the location where the bound states of the closed channel would exist in the absence of the channel coupling (resonances predicted by Feshbach). It is of interest to point out that the so-called "Feshbach resonances", widely used in the BEC-BCS crossover, are not those predicted by Feshbach but they are, actually, potential resonances.

FIRST-ORDER CORRELATION FUNCTION OF THE LIGHT FROM QUANTUM SCATTERERS

Pablo Gabriel Santos

In this work [1], we present a new method to obtain the first-order temporal correlation function, also known as g(1)(τ), for the light scattered by an assembly of point like quantum scatters, for example, quantum dots or a cold cloud of atoms. In this method, instead of the usual configuration using photon- sensible photodetectors (APDs and electron-tubes), we measure the g(1)(τ) in an interferometric setup called mirror-assisted backscattering, and the information about the correlation function is encoded in the contrast of the fringes produced by the light scattered in a cone of directions. We theoretically explore how the contrast of the fringes evolves with the physical parameters of the interferometer like the distance between the scatters and the mirror, but also how controlling the polarization of the incident and reflected light can produce effects that don't vanish after an average of the position of emitters. This polarization control allows the measurement of g (1)(τ) for an assemble of randomly distributed point like scatters. This method has direct application to obtaining the saturated spectrum of quantum systems, with the advantage to be possible assembly the detection scheme around a pre-existent vacuum system since the optics can be positioned far away from the sample (an important condition for samples that needs to be cooled and/or where the optics access is limited). In the end, we discuss some nontrivial aspects of this interferometric setup and propose an analogy with a double Mach-Zehnder interferometer.

Low-lying Excitations of Dipolar Fermi Gases.

Levi Silva

Dipolar quantum gases have established themselves as an important and prolific area of low temperature physics. This is due to the surprising properties found in both fermionic and bosonic gases and they basically come from the anisotropic and long-range nature of the dipole-dipole interaction. In particular, we can highlight the quantum-droplet solutions and their connection with the phenomenon of supersolidity, in the case of Bose gases, and the Fermi surface deformation, properties verified experimentally in recent investigations and which have drawn a lot of attention from the community. In the present work, we intend to study the static and dynamic properties of dipolar Fermi gases in order to characterize the low energy excitations, especially the scissors mode.

FREQUENCY REDISTRIBUTION ON THE FLUORESCENCE OF AN ATOMIC VAPOR

Gessineide Sousa

Radiation trapping is the phenomenon that describes the transport of light by a resonant vapor as a random walk that photons perform inside the vapour, which consists of consecutive events of emission and spontaneous absorption. This phenomenon has been extensively studied in the past in fields such as astrophysics and in the development of steam lamps, and has also become a topic of interest in photon superdiffusion studies. After a scattering event, the frequency of the emitted photon in the laboratory reference can differ from the absorbed frequency due to the Doppler effect. As a result, questions and doubts arise whether there is a correlation between the emitted and absorbed frequencies for regions close to the atomic transition. In this context, we are interested in the effects of this partial redistribution of frequency on light transport in steam. We then demonstrate the partial redistribution of frequency present in an atomic vapor of cesium excited at 894 nm, in resonance with the hyperfine transition 6S1/2 (F = 3) → 6P1/2 (F'= 3, 4) (line D1 of cesium), from fluorescence measurements perpendicular to the excitation laser. The obtained data were interpreted using theoretical models and a numerical simulation that de- scribe the frequency redistribution in the scattering of photons in atomic vapour. It was verified through the results that for excitation close to resonance, the absorption occurs in the center of the line in the atomic reference and the emission is redistributed in the Doppler profile in the laboratory reference. That is, the emitted frequency is not correlated with the absorbed one. However, for excitation far from resonance, absorption is performed far from resonance in the atomic frame of reference and emission also occurs far from resonance, confirming that emitted and absorbed frequencies are therefore correlated. In addition to frequency redistribution, sub- Doppler structures are noted at the center of the line in measurements where the atomic density is intermediate. Furthermore, when the experimental data are compared to the data obtained by numerical simulation, there is a high agreement between the low atomic density fluorescence spectra. Finally, the emission profiles generated by the numerical simulation are close to those predicted theoretically and show the correlation between absorbed and emitted frequencies, in an incident frequency regime close to the atomic transition.

Dynamics of vortices in dipolar BECs with circularly moving potential

Sabari Subramaniyan

We study the creation and dynamics of the vortices in dipolar Bose-Einstein condensates (BECs). First, we calculate the critical velocity of the moving potential for the nucleation of the vortex-dipoles and vortex-clusters in dipolar BECs with respect to the dipole-dipole interaction strengths. Next, we discuss the dynamics of the vortex-dipoles and vortex-clusters in the density of the dipolar BECs.

Quantum-based solution of time-dependent complex Riccati equations

Daniel Martínez Tibaduiza

Using the Wei-Norman theory we obtain a time-dependent complex Riccati equation (TDCRE) as the solution of the time evolution operator (TEO) of quantum systems described by time-dependent (TD) hamiltonians that are linear combinations of the generators of the su(1, 1), su(2) and so(2, 1) Lie algebras. Using a recently developed solution for the time evolution of these quantum systems we solve the TDCRE recursively as generalized continued fractions, which are optimal for numerical implementations, and establish the necessary and sufficient conditions for the unitarity of the TEO in the factorized representation. The inherited symmetries of quantum systems can be recognized by a simple inspection of the TDCRE, allowing effective quantum hamiltonians to be associated with it, as we show for the Bloch-Riccati equation whose corresponding hamiltonian can be related to a generic TD system of the su(2) Lie algebra. As an application, but also as a consistency test, we compare our solution with the analytic solution for the Bloch-Riccati equation considering the Rabi frequency driven by a complex hyperbolic secant pulse generating spin inversion, showing an excellent agreement.

Detection of Rydberg atoms in a dipole trap using EIT spectroscopy.

Lucía Velazco

We describe an experimental set up for the excitation and detection of Rydberg atoms in a dipolar trap, where we have used Electromagnetic Induced Transparency (EIT) to detect them. In the experiment, we first cool 10^8 Rb87 atoms in a magneto-optical trap to 10 micro Kelvin. To trap and control the position of a subset of the cold atomic cloud, we use an optical dipole trap or optical tweezer. This trap is created by two counter-propagating laser beams, tuned out of resonance, and focused on the atomic cloud. These atoms are then excited to a Rydberg state with two laser beams, a blue beam with wavelength 474 nm and an infrared beam with wavelength 795 nm. The EIT spectroscopy is carried out on the infrared beam absorption through the atomic cloud. This setup will be used to study dipole-dipole resonant interactions between Rydberg atoms using EIT spectroscopy.

Conditions for an atomic Bragg mirror around an optical nanofiber N.Vera, P. Solano

Nicolas Vera

Optical nanofibers are experimental platforms that can be used for trapping and interfacing laser cooled atoms with radiation. Trapping is produced due to evanescent fields leaked outside the fiber cladding. Stationary wave conditions allow for a periodic atom trapping structure, which can be used for studying Bragg conditions with 1D lattices of alkali atoms. We explore the necessary conditions (fiber radius and trapping field wavelength) for such purposes.

Spectral broadening and compression of green femtosecond pulses

Fernando Villanueva

Although spectral broadening and subsequent phase compensation as a means for obtaining shorter pulses has been practiced for decades [1], this could only be carried out in optical fibers. By using more powerful lasers, the distance over which spectral broadening occurs can be drastically reduced, allowing for the use of bulk media [2]. Although the technique has been refined over the last decade, to date there are few publications which worked with green light [3]. Using a 12 mm thick fused silica plate, we managed to obtain a spectral bandwidth broadening factor of 3 before damage by photoionization occurred. By changing the Kerr media to an array of four 1 mm thick glass plates, a broadening factor of 5.8 was obtained. Using a grating pulse compressor in the Treacy configuration [4], an attempt to compensate the group delay dispersion (GDD) was made. Phase compensation was not optimal due to the high nonlinearity of the spectral broadening, resulting in a compression factor of 1.3 for the fused silica plate. Currently, we are working on adding spatial filtering and frequency resolved optical gating (FROG) [5] measurements to our setup, as well as improving our pulse compressor's efficiency.