INTERNATIONAL CONFERENCE
ON THE PHYSICS OF LIGHT MATTER COUPLING
IN NANOSTRUCTURES - 16th PLMCN-2015

UNIVERSIDAD
DE ANTIOQUIA
1803
INTERNATIONAL
CONFERENCE ON THE PHYSICS
OF LIGHT MATTER COUPLING IN
NANOSTRUCTURES -
16th PLMCN-2015
February 03th-08th

PLMCN2015
UNIVERSIDAD DE ANTIOQUIA
Alberto Uribe Correa-Rector

FACULTAD DE CIENCIAS EXACTAS Y NATURALES
Nora Restrepo-Decana

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Ricardo León Restrepo Arango, Escuela de Ingeniería de Antioquia
On behalf of the organizing committee, I warmly welcome you to Medellin-Colombia and to the PLMCN2015 conference. This international meeting will give you an opportunity to enjoy presentations and discussions related to the rapidly advancing field of light-matter coupling in nanostructures.


The fields of interest have been adapted to the active developments and new emerging topics of research. The conference has become a platform for new research cooperation between senior and young scientists, academy and industry.

In 2015, the PLMCN conference will be held in Medellin-Colombia, at the University of Antioquia (UdeA) in cooperation with University of Medellin (UdeM), School of Engineering of Antioquia (EIA), and the Mediterranean Institute of Fundamental Physics (Rome, Italy). The conference is sponsored by Quantum Design (www.americanisch.com).

We do hope you will enjoy the traditions and culture of friendly Colombian people, the beautiful landscapes and the comfortable weather in Colombia!

Carlos A. Duque
Program of the 16th International Conference on Physics of Light-Matter Coupling in Nanostructures
Medellin, Colombia, 3-8 February 2015

Tuesday 03.02.2015
Arrival of the participants
19:00  Welcome reception, Universidad de Antioquia

Wednesday 04.02.2015, Universidad de Antioquia

8:45  9:00  Opening

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<td>9:00</td>
<td>1</td>
<td>Luis Viña</td>
<td>Light-matter condensates in 1D: quantum interference in reciprocal space</td>
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<tr>
<td>9:30</td>
<td>1</td>
<td>Igor Bondarev</td>
<td>Excitonic complexes in quasi-1D semiconductors</td>
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<tr>
<td>9:50</td>
<td>1</td>
<td>Juan Pablo Vasco</td>
<td>Study of the radiative coupling between quantum dots embedded in photonic crystal dimers</td>
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<tr>
<td>10:10</td>
<td>1</td>
<td>Carlos Duque</td>
<td>Donor impurity related second and third harmonic generation in GaAs-(Ga,Al)As 3D coupled quantum dot-rings under electric field</td>
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10:30 11:00  Coffee break

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<td>2</td>
<td>Pavlos Lagoudakis</td>
<td>Vortex formation in a Lattice Polariton-Condensate</td>
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<tr>
<td>11:30</td>
<td>2</td>
<td>Anton Nalitov</td>
<td>Polariton Topological Insulators</td>
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<tr>
<td>11:50</td>
<td>2</td>
<td>Carlos Mera Acosta</td>
<td>Effects of bulk backscattering in photon dressed electronic states in topological Dirac Fermions</td>
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<tr>
<td>12:10</td>
<td>2</td>
<td>Juan Carlos Granada</td>
<td>Plasma excitations of the waveguide type in thin metal films of doped topological insulators</td>
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12:30 14:00  Lunch

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<td>14:00</td>
<td>3</td>
<td>Maria Vladimirova</td>
<td>Pump-Probe Spin Spectroscopy of Indirect Excitons</td>
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<td>3</td>
<td>Miguel Eduardo Mora Ramos</td>
<td>Indirect excitons in atomic-layer doped systems</td>
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<td>15:00</td>
<td>3</td>
<td>Mauricio Londoño</td>
<td>Direct and indirect exciton transitions in lateral coupled GaAs (Ga,Al)As quantum dots under applied electric field</td>
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15:20 15:50  Coffee break

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<td>Yasutomo Ota</td>
<td>Recent advance in quantum dot cavity quantum electrodynamics</td>
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<td>16:30</td>
<td>4</td>
<td>Zhanghai Chen</td>
<td>Polariton weak lasing in ZnO microwires</td>
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<td>17:00</td>
<td>4</td>
<td>Alexey Kavokin</td>
<td>Magnetic field effect on polariton and photon lasing</td>
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<td>17:20</td>
<td>4</td>
<td>Robert Brückner</td>
<td>Bloch States, Tamm Plasmons, and Coherence in Organic Micocavities</td>
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Thursday 05.02.2015, Universidad de Medellín

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<td>Pavlos Savvidis</td>
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<td>Emilio Cancellieri</td>
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<td>Eugenia Cherotchenko</td>
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<td>10:10</td>
<td>10:30</td>
<td>Konstantinos Daskalakis</td>
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### 10:30 - 11:00 Coffee break

**Chair:** Hugo Flayac

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<td>Jairo Ricardo Cardenas</td>
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<td>12:00</td>
<td>12:20</td>
<td>Juan Diego Zapata</td>
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<tr>
<td>12:20</td>
<td>12:40</td>
<td>Oleg Kibis</td>
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### 12:40 - 14:20 Lunch

**Chair:** Luis Viña

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<td>Sven Höfling</td>
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<td>14:50</td>
<td>15:20</td>
<td>Konstantinos Lagoudakis</td>
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<tr>
<td>15:20</td>
<td>15:40</td>
<td>Stanislav Moshkalev</td>
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<tr>
<td>15:40</td>
<td>16:00</td>
<td>Anton Tiuttiunyk</td>
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### 16:00 - 16:30 Coffee break

### 16:30 - 18:30 Poster session

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**Friday 06.02.2015**

**Excursion to "Guatapé" Lake and "El Peñol" Stone: 8:30 am to 18:00 pm**

**Saturday 07.02.2015, Universidad de Antioquia**

**Session 8**

**Chair:** Natalia Borloff

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<td>9:30</td>
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<td>Fabrice Laussy</td>
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<td>9:50</td>
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<td>Alexandra Sheremet</td>
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<td>10:10</td>
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<td>Juan Restrepo</td>
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<td>11:00</td>
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<td>Vladimir Kalevich</td>
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<td>Karol Winkler</td>
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<td>Hugo Flayac</td>
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<td>12:10</td>
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<td>Mario Zapata-Herrera</td>
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<td>15:00</td>
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<td>Pedro Pereyra</td>
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<td>15:50</td>
<td>Session 9</td>
<td>Isaac Hernandez Calderón</td>
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<td>Daoud Mezzane</td>
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<td>16:40</td>
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<td>Vyacheslav Elyukhin</td>
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<td>17:00</td>
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<td>Avner Neubauer</td>
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<td>17:20</td>
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<td>Francisco López</td>
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<td>1</td>
<td>Self-assembling of carbon and Sn in Ge:(C, Sn), Vyacheslav A. Elyukhin</td>
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<td>2</td>
<td>Self-assembling of impurity clusters in AlN:(Ga, BV, CV), (BV, CV = P, As, P, Sb: As, Sb), Vyacheslav A. Elyukhin</td>
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<td>Non-equilibrium transport and spin dynamics in single-molecule Magnets, B. Tanatar</td>
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<td>The polaritonic spectrum of 2D photonic crystals based on uniaxial polar materials, H.A. Gómez-Urrea</td>
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<td>The polaritonic spectrum of 1D photonic crystals based on uniaxial polar materials, H.A. Gómez-Urrea</td>
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<td>Charge distribution instability in impurity doped nanocone, W. Gutiérrez</td>
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<td>Stark effect in magneto-exciton confined in GaAs/AlGaAs nanotube, F. Santos</td>
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<td>Studying the electronic and optical properties of lignosulfonates for the development of new materials, Salazar Valencia Pablo Javier</td>
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<td>Effect of a High Intensity laser beam on impurity binding energy in a nanocone, Carlo L. Beltrán Rios</td>
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<td>Structure and Morphology of InGaAs thin films grown by Magnetron Co-Sputtering on Different Substrates, S. Torres Jaramillo</td>
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<td>Dynamics of the Energy Relaxation in a Parabolic Quantum Well Laser, J. L. Carthy</td>
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<td>Faraday rotation in metamaterial-anisotropic photonic superlattices, J. A. Girón-Sedas</td>
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<td>MAGNETIZATION AND OPTICAL PROPERTIES OF ONE AND TWO PARTICLES IN QUANTUM RINGS, F. A. Rodriguez Prada</td>
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<td>Dependence Of Number Defect With The Modes In 1D Photonic Crystals, Hernando González Sierra</td>
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<td>Plasmon enhanced Raman scattering by hybrid nanotube systems, I.V. Bondarev</td>
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<td>A resonant tunneling diode based on Al1-xGaxAs/GaMnAs/AlAs double-barrier asymmetric structure, J. A. Zúñiga</td>
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<td>Quantum Chaotic Encryption on a NMR Computer, Paola Reyes</td>
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<td>Transport and thermodynamic properties of Biphenyl molecules</td>
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**Physics of light-matter coupling in nanostructures**
Light-matter condensates in 1D: quantum interference in reciprocal space

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Exciton-polariton Bose-Einstein condensates, due to their dual wave-particle nature, share many properties with classical waves as, for instance, interference phenomena, which are crucial to gain insight into their ondulatory character. We show that the use of momentum-space optical interferometry, which avoids any spatial overlap between two parts of a macroscopic quantum state, presents a unique way to study coherence phenomena in polariton condensates.

We address a longstanding question in quantum mechanics: “Do two components of a condensate, which have never seen each other, possess a definitive phase?” [1]. A positive answer to this question is experimentally obtained here for light-matter condensates, [2] created under precise symmetry conditions, in semiconductor microcavities, taking advantage of the direct relation between the angle of emission and the in-plane momentum of polaritons.

Figure 1: Interference fringes observed in the momentum distribution of condensed exciton-polaritons at 35 ps after the excitation of two spatially separated wave-packets.

References
Excitonic complexes in quasi-1D semiconductors

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A configuration space (Landau-Herring) approach [1] that was first implemented earlier in Ref.[2] to evaluate the biexciton binding energy in small-diameter carbon nanotubes (CNs), is developed to obtain the universal asymptotic relations for the lowest energy trion and biexciton binding energies in quasi-1D semiconductors[3]. Trions are shown to be generally more stable (have greater binding energy) than biexcitons in strongly confined quasi-1D structures with small reduced electron-hole masses. Biexcitons are more stable than trions in less confined quasi-1D structures with large reduced electron-hole masses. As such, there is a crossover behavior (Fig.1, top right), whereby trions get less stable than biexcitons as the transverse size of the quasi-1D nanostructure increases – quite a general effect which could likely be observed through comparative measurements on semiconducting CNs of increasing diameters. For a specific case of CNs with diameters ≈ 1 nm, the trion binding energy is greater than that of the biexciton by a factor ~1.4, decreasing with the CN diameter, thus revealing the general physical principles that underlie recent experimental observations[4].

![Figure 1](image)

*Figure 1. (a) & (b), left panel: (a) Schematic of exchange coupling between the two different (but physically equivalent!) 1D ground-state exciton configurations separated by the center-of-mass-to-center-of-mass distance $A$, to form the negative trion state. (b) The coupling occurs in the configuration space of the two independent longitudinal relative electron-hole motion coordinates, $z_1$ and $z_2$, of each of the excitonic configurations, due to the tunneling of the entire system through potential barriers formed by the two single-exciton cusp-type potentials (bottom, also in (a)), between the equivalent states represented by the isolated two-exciton wave functions shown on the top. (c) & (d), right panel: (a) Calculated absolute values of the binding energies of the lowest energy trion (▴) and that of the biexciton (○) as functions of the CN radius (transverse confinement size for a general quasi-1D semiconductor) and the reduced effective mass of the electron and hole, $E_{\text{tr}} < E_{\text{exc}}$, at relatively large transverse confinement sizes and reduced effective masses greater than 0.06$m_0$ ($m_0$ is the free electron mass), consistent with what is known for semiconducting quantum wires [5], while $E_{\text{tr}} < E_{\text{exc}}$ at small transverse confinement sizes and reduced effective masses less than 0.06$m_0$ typical of graphitic systems such as CNs. (b) $E_{\text{tr}}$ and $E_{\text{exc}}$ as functions of effective dielectric constant for the (typical) reduced mass of 0.04$m_0$. Vertical planes show the (6,5) and (9,7) CN radii for which experimental data (Ref.[4]) are available for both $E_{\text{tr}}$ and $E_{\text{exc}}$.*

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References

Study of the radiative coupling between quantum dots embedded in photonic crystal dimers

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We theoretically address the possibility of using strongly coupled photonic crystal (PC) molecules to efficiently increase the mutual coupling rate between two quantum dots (QDs) at large inter-dot distance. A schematic representation of our system is shown in Fig. 1. The photonic molecules we are interested in are composed of two coupled PC slab cavities, or PC dimers. We specifically consider coupled L3 cavities, i.e., three missing holes in a hexagonal lattice. We treat the light-matter coupling with a semiclassical formalism based on Green’s tensors and the classical electromagnetic fields are solved within a guided-mode expansion approach. We have found that when the QDs are in resonance with either of the two lowest energy modes (bonding/antibonding) of the PC dimer, and in the strong cavity-cavity coupling regime, the inter-dot radiative coupling strength is proportional to the quality factors of the dimer modes, and it can be of the order of 1 meV which is at least an order of magnitude larger than typical values achieved in one-dimensional systems. Since these quality factors increase as a function of the inter-cavity distance, then the radiative coupling also increases with distance. Moreover, since the quality factors remain approximately constant at large distances, the radiative coupling also remains constant at inter-dot separations that are significantly larger than their characteristic emission wavelength. In addition, we have also found that when the QDs are out of resonance from the PC dimer modes, the inter-dot radiative coupling is still significant and inversely proportional to the normal mode splitting between photonic states. Finally, through a statistical analysis we have shown that our results are robust against position disorder of the two QDs within their respective cavities [1].

![Diagram](image)

Figure 1: Two strongly coupled nanocavities, each containing a single QD. The distance between the nanocavities, $d_c$, can be larger than the characteristic QD emission wavelength in vacuum, $\lambda_0$.

References
Donor impurity related second and third harmonic generation in GaAs-(Ga,Al)As 3D coupled quantum dot-rings under electric field

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In the present work, the effects of applied electric field on the donor impurity related second and third harmonic in a GaAs-(Ga,Al)As coupled quantum dot-rings are investigated [1,2]. The calculations were performed within the compact density-matrix formalism with the use of the effective mass approximation. The physical system is modeled by two parabolic potentials, which allow changing the in–plane dimensions of the structure through modifications on the frequencies. The third dimension is introduced via a rectangular-finite potential. The eigenfunctions and eigenvalues for the confined carrier are obtained by direct diagonalization of the Hamiltonian in a set of 3D sines functions which are solution of one electron confined in a rectangular quantum box with infinite confinement potential. The obtained results show that both second and third harmonic generation are sensitive to dot-ring dimensions (proportional to the frequencies) and the effects of external electric field. By changing the intensity of the electric field and dimensions of the structure we can obtain the blue or red shift of the main structures, without the need for the growth of many different samples.

Figure 1: Energy of the 15 first confined electron levels in a system of coupled 2D quantum dot-ring as a function of external applied electric field (parallel to the plane of the structure). In (a) and (b) the results are, respectively, without and with on-center donor impurity.

References
Resonance Interaction of Terahertz Radiation with Domain-Nanostructured Multilayered Ferroelectric Materials: Effect of Negative Capacitance

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Polarization domains that alternate the surface charge distribution, first proposed by Landau (1935) and Kittel (1946) in contents of ferromagnetism can be formed in finite-size ferroelectrics as an effective mechanism to confine the depolarization field to the near-surface layer and diminish the depolarization energy. However their existence have long been considered as barely possible until recent direct theoretical predictions [1-3] and experimental evidences [4-5] in thin oxide films and superlattices.

In my talk I will consider the ultra-high-frequency dynamics of few-nanometer wavelength periodic domain structure observed in PbTiO3/SrTiO3 superlattices (Fig 1, left) [6]. The calculated frequency dependence of dynamical permittivity, ε(ω) of thin layer of PbTiO3 with domains (Fig. 1, middle) exhibits striking feature: its real part is negative at low frequencies that is explained by the opposite orientation of the depolarizing field with respect to the field-induced averaged polarization, phenomenon known as "ferroelectric negative capacitance". However, in sub-THz region Re ε(ω) becomes positive, passing through zero at ω = ωc ~ 0.3-3THz.

The resulting collective oscillation mode is associated with domain-wall vibrations. It becomes active in the near-THz frequency region and can be excited and detected by methods of Reflection Absorption Spectrometry. The corresponding reflectivity ∆R/R~Im(1/ε(ω)) reveals the clear resonance at ω ~ ωc for the THz beam, incident at the Brewster angle (Fig 1, middle). This unique property makes ferroelectric films a promising candidate for compact and tunable devices working in the sub- and low THz range.

Figure 1: Periodic domain structure in Ferroelectric / Paraelectric superlattice (left), its dynamic dielectric permittivity (middle) and 2D color map of resonance in reflectivity of p-polarized THz beam as function of frequency and incidence angle (right).

Enhanced terahertz emission by Landau quantization in semiconductor superlattices

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Semiconductor superlattices under a constant electric field present an equally spaced distribution of energy levels along their axe of symmetry known as Wannier-Stark ladder. The energy difference between two consecutive states is proportional to the applied electric field and the spatial period of the superlattice and corresponds to the named Bloch frequency. We use such distribution of levels and its corresponding wave functions to theoretically describe the carrier dynamics in a biased superlattice and the subsequent electric field emission after the application of a short interband light pulse excitation [1][2]. We use the density matrix theory to compute the expectation value of the current operator and then its time-derivative which is associated with the electric field emission. The results show that the average current performs Bloch oscillations whose amplitude depends on the temporal width of the excitation pulse, the excitation energy measured from the concerning Wannier-Stark level, the conduction and valence miniband widths and the Bloch frequency [1]. The first two parameters are defined by characteristics of the laser pulse, the third one depends only on the material composition and geometrical parameters of the SL, while the last one depends on the applied bias and can thus be tuned from outside. In this work, we consider the THz intensity emitted by carriers in biased semiconductor superlattices (BSL) subjected to a magnetic field B/\zeta [2]. Our results demonstrate the essential part played by the spectral distribution of lateral states on the formation of the nonstationary 3D wavepacket in undoped BSL’s by a fast optical pulse together with the purely quantum-mechanical origin of the subsequent vertical THz current. We study in detail the high B regime, where the in-plane motion is frozen in Landau orbits that are spectrally well separated (with respect to the laser pulse width). We show that a quasi 1D Bloch oscillator can be ideally generated in this regime, i.e., an oscillator with decoupled vertical and lateral electron motions. The physical origin of this effect is the freezing of the electron lateral kinetic energy to a fixed value due to the Landau quantization. It implies the suppression of the time dependent destructive interferences that take place at B = 0 between the various components of the wavepackets that have different in-plane kinetic energy. Finally, we shall show that a high magnetic field makes the THz emission by BSL’s more intense and more coherent.

References


Evanescent field interaction of the light with graphene across waveguide D-shaped optical fiber for the ultrashort pulses generation in EDFL

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The graphene is a nanomaterial carbon allotrope which constitutes a completely bidimensional one atom thickness material that have important optical and electronic properties [1, 2]. Because of its high nonlinear optics properties, graphene is used for various applications, for example, generation of ultrashort pulses, four wave mixing generation, optical device construction as modulators and polarizers [2, 3]. All these applications make use of the strong interaction between graphene and the light. There are different mechanisms for propitiating the interaction between light with graphene: depositing graphene on the optical fiber tip; placing graphene on a diminished diameter of a short optical fiber segment or taper configuration; or transferring graphene on D-shaped optical fiber polished surface [2-5].

In this work, our propose is improving the light-graphene interaction using a waveguide in D-shaped optical fiber, as shown in the Figure 1a, for ultrashort pulses generation in an Erbium doped fiber laser (EDFL). For the construction of D-shaped optical fiber, a typical single mode optical fiber with a core diameter of 8 μm and a cladding diameter of 125 μm has been polished in the surface. The distance from the core to the polished surface (h) is 0 μm, and the polishing length (L) is 30 mm. The Figure 1b shows the EDFL ring cavity, where the graphene acts as a passive saturable absorber to produce a passive mode-locking laser. In this device, the graphene filters low intensities and allows passing the higher intensities, generating ultrashort pulses through a feedback in the closed cavity. With this configuration, we generate ultrashort pulses of 464 fs, as it can be seen in Figure 1c, useful for many applications in physics, chemistry, biology and optical communications [1-5].

Figure 1 (a) D-shaped optical fiber with graphene. (b) EDFL cavity setup. (c) Generated pulse width.

References
Aharonov-Bohm effect induced by circularly polarized light

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Progress in modern nanotechnologies has resulted in rapid developments in the fabrication of various mesoscopic objects, including non-singly-connected nanostructures such as quantum rings. The fundamental interest attracted by these systems is caused by a wide variety of purely quantum-mechanical effects which can be observed in ring-like mesoscopic structures. The most notable phenomenon amongst them is the Aharonov-Bohm (AB) effect arisen from the direct influence of a vector potential on the electron phase [1]. In the ballistic regime, this effect results in magnetic-flux-dependent oscillations of the conductance in ring-like structures with a period equal to the fundamental magnetic flux quantum $\Phi_0 = h/e$. In the diffusive regime, a second type of conductance oscillations with the period $\Phi_0/2$ can be observed. They are known as the Altshuler-Aronov-Spivak (AAS) oscillations and are associated with the weak localization of electrons [2].

From a fundamental viewpoint, the AB-AAS oscillations arise from the broken time-reversal symmetry in the electron system (conducting mesoscopic ring) subjected to a magnetic flux through the ring. Namely, the flux breaks the equivalence of clockwise and counterclockwise electron rotations inside the ring, which results in the flux-controlled interference of electron waves corresponding to these rotations. However, the time-reversal symmetry can be broken not only by a magnetic flux but also by a circularly polarized electromagnetic field [3]. Indeed, the field breaks the symmetry since time reversal turns clockwise polarized photons into counterclockwise polarized ones and vice versa. Therefore, phenomena similar to the AB-AAS effects can take place in ring-like electronic systems strongly interacting with a circularly polarized electromagnetic field. Recently, we shown that the conductance of these electron-photon systems can exhibit oscillations which are formally equivalent to the AB-AAS oscillations induced by a magnetic flux [4]. Periods of the optically-induced oscillations in the ballistic regime and the diffusive regime differ from each other by a factor of 2 in the same manner as periods of the oscillations induced by a magnetic flux. The discussed phenomenon can be described in terms of an artificial $U(1)$ gauge field generated by the strong coupling between electrons and circularly polarized photons. The theory of such an optically-induced AB effect, which lies at the border between condensed-matter physics and quantum optics, will be presented in the given talk.

References

Pump-Probe Spin Spectroscopy of Indirect Excitons

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Semiconductor coupled quantum wells (CQWs) offer an excellent laboratory for studying both intra-well direct excitons (DX) and inter-well indirect excitons (IX), as well as their interactions and spin dynamics. The presentation will focus on the pump-probe spectroscopy, a powerful tool of nonlinear optics, that we have applied to biased CQW (see Figure). We will show how DX and IX spin and population dynamics, as well as the spin polarization of residual electrons may be detected via the modulation of reflectivity and Kerr rotation spectra. In particular, the origin of the nonlinearities related to the low oscillator strength IXs will be addressed [1]. Spin relaxation mechanisms for DX, IX and electron gas will be presented [2].

Figure 1: (a) Sketch of CQWs and the corresponding band diagram with direct (DX) and indirect (IX) exciton transitions (b) Three-level scheme of the pump-probe experiment with relevant excitonic states in a biased CQWs. Low oscillator strength IX states are pumped and probed via DX transition, through their common ground state.

References

Indirect excitons in atomic-layer-doped systems

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Atomic layer doping (ALD) implies the insertion of a very thin layer with a high density of ionized dopant atoms into an otherwise homogeneous semiconductor matrix. The possibility of introducing adjacent layers of different type (n and p) gives rise to the appearance of separate confinement of charge carriers in the conduction and valence bands as shown in the Fig. 1. Accordingly, the electrostatic coupling between electrons and holes leads to indirect exciton states. In this paper, we propose this novel environment for the indirect exciton complex and investigate its properties in a GaAs ALD quantum well system, taking into account different values of the separating distance between the n-type and p-type delta-doping layers, and use a Thomas-Fermi approach to describe the potential energy band profiles. Conduction band states are calculated by solving the single-band effective mass Schrödinger equation, whilst the \(6 \times 6 \mathbf{k} \cdot \mathbf{p}\) model allows to obtain the coupled hole states. Exciton energies and wavefunctions are then computed via a diagonalization procedure that uses an orthogonal basis constructed from the uncorrelated electron and hole eigenfunctions and the purely two-dimensional exciton states. With the information about indirect exciton properties, the coefficients of linear and nonlinear optical absorption are calculated for some inter-exciton-state transitions in the THz range.

![ALD–QW–Potential energy profile (schematic view)](image)

Fig. 1
Direct and indirect exciton transitions in lateral coupled GaAs-(Ga,Al)As quantum dots under applied electric field

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The present work deals with a theoretical study of the effects of applied electric field on the direct and indirect exciton transitions in lateral coupled GaAs-(Ga,Al)As quantum dots [1-3]. The calculations were performed within the effective mass and parabolic band approximations. To find the uncorrelated electron-hole wave functions we apply a numerical meshless scheme for solving the one particle time independent Schrödinger equation by means of collocation method with Radial Basis Functions interpolants [4]. In particular we approximate the solutions using multiquadrics. The Coulomb interaction is considered using a variational procedure with one parameter hydrogenic trial wave function. Different configurations of the two coupled dots are reported (dot radius, separation between dots, and applied electric field). Our results include the exciton binding energy, photoluminescence energy transition, oscillator strengths, and relaxation time.

Figure 1: Energy of the confined electron levels in a system of coupled two-dimensional quantum dots as a function of separation between the centers of the dots.

References
Recent advances in quantum dot cavity quantum electrodynamics

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Semiconductor quantum dots in photonic crystal nanocavities offer a unique opportunity for the research of cavity quantum electrodynamics (QED), owing to their strong light matter interaction at a single quantum level on the simple and robust platform. Currently, we are pushing the research forefront by increasing cavity quality factor and reducing mode volume by elaborating the semiconductor nanofabrication and cavity design. These lead to a longer and tighter optical confinement, and hence stronger coupling between the emitter and cavity photons, enabling further sophisticated cavity QED experiments. We are also developing a spectroscopy technique that can access direct free space spontaneous emission from a single quantum dot strongly coupled to a nanocavity. In this talk, we will discuss these recent advances in quantum dot cavity QED in our group.
Polariton weak lasing in ZnO microwires
Zhanghai Chen
Magnetic field effect on polariton and photon lasing

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We study experimentally the polariton and photon lasing threshold as a function of magnetic field applied in the growth direction of a microcavity. Our samples included high finesse (Q-factor about 200000) planar and pillar GaAs microcavities providing an access to different values of the exciton-photon detuning and allowing for both optical pumping and electronic injection. The photoluminescence measurements were performed at temperature $T = 3$ K and the peak wavelength at approximately 805 nm. This wavelength corresponds to the lower polariton branch and at the experimental temperature the clear transition to polariton lasing regime is observed at increasing pump powers.

Surprisingly, we have found that the applied magnetic field can lead to reduction of the photonic lasing threshold power at small fields followed by the increase of the threshold with the increase of the field. This regime takes place only for the excitation spot of the small size (with the diameter $< 10$ µm) whereas for the larger spots (diameter $> 100$ µm) the monotonous behavior of the threshold is observed. Those intriguing effects can be explained within the theoretical model, which accounts for spreading of electron-hole plasma in-plane of the sample due to diffusion, as well as for suppression of the diffusive processes by magnetic field. We note that to describe the experimentally observed increase of the exciton density (leading to the threshold decrease) both the diffusion coefficient of electrons and holes and the rate of excition formation from electron-hole plasma are to be taken field-dependent. For the narrow spot the diffusion of charged carriers from the excitation spot results in lowering of the exacton density under the excitation spot, thus increasing the threshold. At stronger magnetic fields, the exciton lifetime decreases due to the shrinkage of the wave-function of electron-hole relative motion. This results in the decrease of exciton concentration and, consequently, by the increase of threshold power. This effect is independent on the size of excitation spot. Magnetic field, however, suppresses the diffusion and it enhances the excition formation rate. A good qualitative agreement of theory and experiment has been achieved (Figure 1). Note the qualitative difference between the threshold dependence on the pump spot size: the threshold monotonously increases with the field in the case of a large spot, where the diffusion effect is not important, and only the lifetime shortening plays role. On the other hand, for a small spot, the dependence is non-monotonic, reflecting the important role of suppression of diffusion at low fields.

![Graph](image.png)

Figure 1. Experimental (left panel) and theoretical (right panel) dependences of the lasing threshold on longitudinal magnetic field. The red and blue dots lines correspond to different diameters of the excitation spot: 10 µm and 100 µm, respectively. Note the non-monotonous behavior for the narrow excitation spot.
Bloch States, Tamm Plasmons, and Coherence in Organic Microcavities

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Utilizing organic small molecules for optoelectronic devices enables fascinating applications, e.g. organic light emitting diodes or solar cells. Even devices for logic applications such as thin film transistors are under intense study. Furthermore, the interaction of light and matter, i.e. between a photon and an exciton can be studied and various coherent phenomena such as Bose-Einstein condensation and lasing have been reported. We focus on coherent properties of organic microcavities with embedded superlattices of silver or SiO$_2$. Metallic structures can perspective be used as highly conductive electrodes. The large absorption of metals is usually detrimental to lasing, however, by clever engineering the mode structure and exploiting the intrinsic properties of Tamm plasmons, we can show coherence of the latter in low-loss devices [1]. The particular electrode structure, designed as periodically placed deep photonic wires forming a superlattice, allows for studying another fundamental effect [2]. Below the confining potential, photons are confined to discrete dispersion-less modes, above the potential, Bloch-like bands including mini bandgaps can be observed, see Fig. 1. Applying a Kronig-Penney-like theory, we can analytically describe the entire far-field emission pattern of our cavities and can predict the emergence of either zero, π, or 2π phase-locked states in the system. In a sample with an integrated SiO$_2$ grating, we observe a similar Bloch-like band structure of highest quality and show the control of the coherent emission by creating different gain patterns in space. Both the spatial distribution and the dispersion exhibit coherent emission from tunable modes. The results are analytically and numerically modeled – in perfect agreement with our measured data.

References

Figure 1: Far-field pattern of a metal-organic microcavity. Above the confining potential (<656 nm), Bloch-like modes propagate. Below the potential (684-656 nm), discretized Tamm plasmon polariton modes are observed. Grating period is 111 nm.
Pattern Formation In Interacting Exciton-Polariton Condensates

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Strongly coupled semiconductor microcavities support the formation of exciton-polaritons, which can condense into macroscopically occupied quantum states or quantum liquids. The investigation of such systems revealed a number of effects commonly associated with the formation of a macroscopic phase, for instance superlattice-like behavior[1] or the appearance of quantized vortices. One of the focal points of current research regards the possibility of optically manipulating polariton condensates to realize new experiments and potential applications like all-optical polariton circuits. We develop this vision by employing a spatial light modulator to create arbitrary excitation patterns, where nonresonant excitation of polariton condensates allows us to define the potential landscape experienced by the condensates.

Novel effects regarding the interaction of multiple polaritonic quantum liquids are revealed, in particular phase-locking between freely-flowing condensates[2], the formation of vortex lattices for multiple pump spots at large separations and the transition to a trapped configuration as the pump spots are moved closer together[3,4]. These results enhance our ability to explore new features in macroscopic coherent systems and bring us closer to practical applications with polariton condensates such as creating alloptical coherent circuits[5].

References

[4]. A. Dreismann et al., PNAS 111, 8770 (2014)
Spin vortices and anti-vortices formed by polariton condensate in a concave-planar open microcavity

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In strongly-coupled microcavities, quantized vortices have been observed as topological defects revealing the quantum fluid nature of exciton-polariton condensates. It has also been shown that vortices can be used for encoding quantum information [1]. Recently, the interplay between disorder and birefringence in CdTe cavities enabled the observation of spin vortices, which emit photons with spatially varying polarization [2]. Spin vortices can also be generated by effective spin-orbit (SO) coupling in a microcavity with an engineered circular potential. In this paper, we present a novel method to generate spin vortices and to flexibly control the SO coupling using an open microcavity. The system consists of a bottom semiconductor distributed Bragg reflector (DBR) with near-surface quantum wells (QWs) and a top dielectric concave DBR separated by a micrometer sized gap. Nanopositioners allow positioning of the DBRs to form a hemispherical cavity and the spectral resonance can be tuned by controlling the separation [3]. The open cavity exhibits strong exciton-photon coupling and polariton condensation at 4K. The SO coupling in such cavity structures enables the observation of spontaneously-formed polariton states with non-trivial spin textures, such as spin vortices (Figure 1a) and spin anti-vortices (Figure 1b) which exhibit polarization angles co-rotating and anti-rotating with real-space, respectively. Quasi-spin vortices (Figure 1c) arising from higher order optical modes display more complicated features, with polarization degree and direction both varying in space. Interestingly, the exciton/photon fraction of the polaritons is found to have a determining effect on the resulting spin texture: spin vortices switch to linearly polarized condensates when the SO coupling is weakened by increasing the exciton fraction. This observation robustly evidences the strong influence of the matter/light character of polaritons on their spin textures, providing a promising method to freely manipulate and control the spin dynamics of polariton condensates.

Figure 1. Measured linear polarization angle (left panels) and schematics (right panels) of spin vortex (a), spin anti-vortex (b) and quasi-spin vortex (c) formed by SO coupling in the open microcavity structure.

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References

Superconductivity in Semiconductor Structures: the Excitonic Mechanism

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We study theoretically the effect of the fermion and boson densities on the superconductivity transition critical temperature ($T_c$) of a two dimensional electron gas (2DEG), where superconductivity is mediated by a Bose-Einstein condensate of exciton-polaritons. The critical temperature is found to increase with the boson density, but surprisingly it decreases with the 2DEG density increase. This makes doped semiconductor structures with shallow Fermi energies better adapted for observation of the exciton-induced superconductivity than metallic layers. For the realistic GaAs-based microcavities containing doped and neutral quantum wells we estimate $T_c$ as close to 50 K. Superconductivity is suppressed by magnetic fields of the order of 4T due to the Fermi surface renormalisation.

Figure 1: Left panel: The dependence of the critical current $j_c$ on the temperature and electron concentration. Right panel: Fermi wave vector (red curve) and critical temperature (blue curve) as a function of magnetic field $B$. $N_e = 8 \cdot 10^{11} \text{cm}^{-2}$. The Dingle broadening of Landau levels $\Gamma$ is taken to be 0.3 meV, that corresponds to the cyclotron energy $\hbar\omega_c$ at $B = 0.2$ T.

References
Coherence and stability in organic polariton condensates
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In the last few years, organic microcavities have shown polariton condensation that can readily be realized at room temperature [1,2,3]. The sudden appearance of off-diagonal long range order in coordinate space has been recognized as a defining feature of polariton condensates. In this report, we use a Michelson interferometer in a mirror-retroreflector configuration to measure the spatial coherence of a polariton condensate using a thermally evaporated film of the oligomer 2,7-bis[(9,9-di(4-methylphenyl)-fluoren-2-yl)]-9,9-di(4-methylphenyl)fluorene (TDAF). Above threshold, we find that the spatial coherence increases sharply and then flattens. For a small Gaussian excitation spot (~20 μm FWHM), the condensate extends over the entire pump region. We measure g(2)(r)-r) values of nearly unity at short distances and of 50% for points separated by nearly 10 μm. The spatial and temporal coherence are found to decrease with increasing pump power due to the pulsed excitation scheme. Moreover, the intensity pattern above threshold shows non-uniformities similar to those observed for localized condensates in disordered II-VI cavities [4]. Despite the non-uniform intensity pattern, clear parallel fringes indicate a flat phase over the entire condensate area. In contrast, measurements with larger Gaussian pump spots and different pump shapes are shown to lead to highly localized condensate formation, which vary with position on the sample, accompanied by distorted speckle-like interference patterns. With increasing excitation density, spatial fluctuations in the intensity pattern is observed, which is in stark contrast to an equilibrium Bose-Einstein condensation. In BUC, the increasing excitation density will screen any spatial disorder resulting to a uniform emission profile.

Figure 1. (a) Schematic showing the fabricated structure which consists of two dielectric mirrors of alternating tantalum pentoxide (Ta2O5) and silicon dioxide (SiO2) planes enclosing a single layer of TDAF. The molecular structure of TDAF is shown between the mirrors. (b) The spatial coherence at various locations away from the condensate center r = 0 μm shown for increasing pump fluence.


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Vortex formation in a Lattice Polariton-Condensate

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Spontaneous vortices are topological defects resulting from a symmetry breaking process in a system when it undergoes a phase transition. Recently, there has been a great deal of interest in the experimental observation of topological objects in Bose-Einstein condensates of exciton-polaritons (Nature Physics 4, 706 (2008), Science 326, 974 (2009), Science 332, 1167 (2011)). Self-organization in bosonic condensates attracts a great interest as it sheds light on the mechanisms of spontaneous processes in nature. Curiously, the vorticity observed in these and the following works the vortices appeared to be pinned to structure imperfections and their winding numbers being defined by the excitation conditions. Here I will present evidence of vortices in the phase relation between neighboring sites of a polariton lattice condensate. It will be shown that such mesoscopic vortices are formed in the process of condensation in an interacting lattice and are independent of structural imperfections.

Figure 1 (a) The trivial case for phase locking of three condensates where all of them are in phase is shown. The system is rotationally symmetric and there is a constructive interference at the center of the lattice (marked by a black arrow). (b) The three condensates could spontaneously break the rotational symmetry and phase lock with a ±2π/3 phase difference between adjacent neighbors, which correspond to clockwise or anticlockwise vortices with winding numbers of ±1.

The simplest spatial configuration where such vortices can occur is that of a triangle. In the case of an equilateral triangle in real space and under pulsed excitation the phases of the individual polariton at some stage lock. If they lock in phase, no vortices appear, while if they lock with specific phase-shifts vortices with winding numbers of −1 or -1 are formed stochastically (see Fig. 1). Analysis of the dynamics of the vortex formation reveals that the coupling mechanism is dissipative similar to the one in the classical Huygens’s clocks.
Polariton Z Topological Insulator

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Figure 1: Left panel: a schematic sketch of polariton Z topological insulator. Honeycomb lattice etched out of a microcavity is placed in external magnetic field. Edge states are optically excited and propagate without scattering backwards and into the bulk. Right panel: the lowest bands of the polariton energy dispersion. A gap opens between the Dirac cones due to the interplay of spin-orbit coupling and external magnetic field. The one-way edge states in the gap are topologically protected from scattering.

We demonstrate that honeycomb arrays of microcavity pillars, or polaritonic graphene [1], behave as an optical-frequency 2D photonic topological insulator of type Z under application of external magnetic field. We show that the interplay between the photonic spin-orbit coupling, natively present in this system due to TE-TM splitting [2], and the Zeeman splitting of exciton-polaritons in external magnetic fields leads to the opening of a topologically non-trivial energy gap characterized by \(C_m = \pm 2\) set of band Chern numbers and to the formation of topologically protected one-way edge states [3]. This result stands for other physical realizations of honeycomb potentials for polaritons [4].

References
Effects of bulk backscattering in photon dressed electronic states in topological Dirac Fermions

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The realization of a spintronic device using topological insulators is not trivial, because there are inherent difficulties in achieving the surface transport regime. The majority of 3D topological insulators materials (3D TI) despite of support helical metallic surface states on an insulating bulk, forming topological Dirac fermions protected by the time-reversal symmetry, exhibit electronic scattering channels due to the presence of residual continuous bulk states near the Dirac-point. From ab initio calculations, we studied the microscopic origin of the continuous bulk states in rhombohedral topological insulators materials with the space group $D_{3h}^2(R3m)$, showing that it is possible to understand the emergence of residual continuous bulk states near the Dirac-point into a six bands effective model, which is not possible in conventional models. We studied the effects of the bulk states in the photon dressed electronic states in rhombohedral topological insulators, showing that the conductance for the surface model is modified in the presence of bulk states. The mechanisms known to eliminate the bulk scattering, for instance; the stacking faults (SF), electric field and alloy, are a way to retrieve the energy gap and energy dispersion of photon dressed electronic states in the 3D topological insulators [1].

References

Plasma excitations of the waveguide type in thin metal films of doped topological insulators

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Electromagnetic excitations in systems with non trivial topology associated to time reversal symmetry (topological insulators) have been the subject of interest during last years [1-5]. In this work the electromagnetic excitations arising in a doped thin film of a topological insulator are described within a Green function formalism developed in the frame of axion electrodynamics [6]. It is shown that in the long wavelength non retarded limit the rotation of the polarization plane induced by the non trivial topology is a linear function of the topological term for all slab thicknesses. On the other hand, in the retarded limit, the topological term causes a splitting of the frequencies of the homogeneous waveguided modes, which depends on the square root of the topological term and depends inversely on the slab thickness. Additionally, a low frequency mode of the helicon type is found, with frequencies much lower than the characteristic frequencies of the waveguided modes and increasing with the square of the in-plane wave vector.

References
Semi-conductor Quantum Dot Microcavities: From Coherent Single Photon Emission to Single Spin-Photon Interaction

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Single semiconductor quantum dots (see fig.1) are regarded as artificial atoms hosted in a solid-state platform. They enable one to capture charges, excitons and spins at the single quantum level and to generate on-demand single photons, entangled photon-pairs and establish spin-photon interfaces. While accomplishing all this in a solid-state platform is a major advantage for applications in quantum information processing and quantum sensing, the solid-state environment poses particular challenges in overcoming decoherence phenomena compared to single well isolated atoms. In this presentation, single quantum dots and there general coherence properties will be described. The emphasis is two-fold, on the generation of coherent single photons with high degrees of indistinguishability and on spin-photon interactions with spins as quantum memories in quantum dots. Enhanced light-matter interaction in microcavities will be discussed and its impact on improved characteristics will be discussed.

Figure 1: Scanning tunneling electron microscopy image of an InGaAs/GaAs semiconductor quantum dot.
Coherent control and optical pumping of spins in self-assembled and site-controlled quantum dots

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The qubits of large scale quantum information processing (QIP) platforms according to the Di Vincenzo criteria require robustness to the surrounding environment and scalability [1]. Although electron spins in self-assembled quantum dots have been shown to be good candidates for all optical ultrarapid coherent control [2], they suffer from feedback coming from the surrounding nuclear spin bath. Hole spins on the other hand, have been shown to be more robust, but up to now positive charging of quantum dots is achieved through the use of p-i-n diode structures [3] that involve extremely difficult fabrication processes and require external electric control with the potential of introducing additional noise sources [4]. Here, we have grown self-assembled p-type δ-doped InAs quantum dots and demonstrate individual hole spin pumping and repumping [5] with a traditional two-laser as well as a novel one-laser scheme while theoretically investigating the parameter space for which the one laser scheme holds. To address the scalability we also investigated a novel type of site controlled InAsP quantum dots embedded in InP nanowires [6] and were able to achieve optical spin pumping [7]. We investigated current limitations and propose ways to ameliorate the properties in view of paving the way towards complete coherent control in scalable platforms.

Figure 1: (Left) Polarization selection rules for a typical four level system created when a charged quantum dot is exposed to high magnetic field in the Voigt Configuration. (Center) Complete coherent control of an individual electron spin in a self assembled quantum dot. (Right) Spin pumping of an individual spin in a site controlled InP nanowire quantum dot

References
CdSe-ZnS quantum dots/multilayer graphene hybrid structures for photoactive cell
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As highlighted by the great number of recent publications, graphene proved to be greatly suitable for numerous nanoelectronic applications. Graphene presents high carriers mobility and, combined with quantum dots (QDs) with effective light absorption, can be a very interesting short-response-time hybrid material for future optoelectronic nano-devices[1].

In this work, we present the fabrication and first test results of photosensitive hybrid structures based on multilayer graphene (MLG) covered with CdSe-ZnS QDs. The MLG plates were prepared by liquid phase exfoliation of natural graphite [2] and subsequently deposited over metallic electrodes by dielectrophoresis (Fig. 1a). The micron size gap (0.9–1.1 µm wide and 1.5 µm deep) was previously open between the electrodes by focused ion beam. After deposition, the MLGs connect the electrodes in a resistor configuration. Next, the samples were treated at 700°C in high vacuum in order to improve the electrical contact between MLG and metal.

Suspension of CdSe-ZnS QDs (diam. 5.3 nm, luminescence peak ~ 630 nm) was prepared in toluene (~10¹⁰ mol L⁻¹) and deposited by drop coating in the region between electrodes.

First experiments showed good responsiveness of QD/MLG hybrid structure to laser spot illumination. Raman measurements (473 nm laser, laser spot of 0.5 µm) detected high luminescence on graphene surface. In order to investigate the sensing response, time-current characteristic curves were recorded for dark-illumination regime. The excitation light used was a 532 nm green laser with an output power of 5 mW.

After the first illumination cycle, a good photoresponsivity (~30 mA W⁻¹) was detected. This response decreases with further light-on-light off cycles down to 4-8 mA W⁻¹ (Fig. 1b). The photoinduced conductivity can be explained through two mechanisms. The first one is the occurrence of the photoinduced conductivity due to charge transfer from quantum dots to graphene [3]. The second one can be due to a transfer of energy by dipole-dipole interactions which affects indirectly the increase of conductivity [4]. This dipole interactions occur from the approximation of quantum dots as point dipoles.

Hence, we have demonstrated that the QDs-MLG hybrid structure can be used as a photoactive cell. Work is now in progress for improving the photocurrent response of this hybrid material through different structural changes, such as deposition method and layer thickness of QDs, metal type, different illumination sources, among others.

Fig. 1. (a) SEM image of a MLG/QDs hybrid structure connecting the metallic electrodes; (b) photoresponse measurements for a MLG/QDs sensor submitted to repeated light-on-light off cycles.

References
Study of electron-related optical properties in three coupled triangular quantum dots

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This work concerns theoretical study of confined electrons in a low-dimensional structure consisting of three coupled triangular GaAs/Al_{0.6}Ga_{0.4}As quantum dots (see figure. 1), and it is based on the technique described in Ref. [1]. Calculations have been made in the effective mass and parabolic band approximations. In the calculations we have implemented a diagonalization method to find the eigenfunctions and eigenvalues of the Hamiltonian. We got value and made a comparative analysis of linear and nonlinear optical absorption coefficients and the relative change in the refractive index, which is tied to the intersubband electron transitions. Our results include the discussion of the electron photoluminescence energy transition as a function of dimensions of the structure and different positions of triangles.

Figure 1: Schema of three coupled quantum dot structure considered in this work

References
Oscillatory regimes of a coupled two-component linear-nonlinear bosonic system

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Inspired by the most recent research on Rabi oscillations of exciton-polaritons [1–3], the present work aims to investigate the internal Josephson phenomena in the Bose-Einstein condensate of exciton-polaritons as a two-state condensate of photons and excitons performing mutual resonant transformations.

We consider Bose-condensed polariton system as a mixture of the two coupled linear (non-interacting) and non-linear (interacting) components, with the detuning between the photon and exciton modes at resonance [4]. The system is described by the coupled Schrödinger and Gross-Pitaevskii equations for macroscopic wave functions of the photon and exciton condensates, respectively. This approach has proved useful in our previous investigations [5,6]. The two parameters that influence the type of dynamics are total number of polaritons in the condensate and the effective detuning between the modes. We assume \( T = 0 \) and take no account of particles gain or dissipation. Those non-equilibrium effects are subject to separate investigation.

For the symmetric case of zero effective detunings, we show that the regimes of dynamics are analogous to those in bosonic Josephson junction (i.e., the possible regimes are harmonic and unharmonic Rabi oscillations, internal Josephson “plasma oscillations” and macroscopic quantum self-trapping of populations), although we argue that for the specific case of exciton-polaritons, only the Rabi regime can be realized. For the asymmetric case, we show that for different detunings values the Rabi oscillations between the two particle states are replaced by an analog of internal a.c. Josephson effect. Also, we predict that there is a defined value of the energy detuning close to zero yet depending on the initial population imbalance, at which the internal oscillations are fully suppressed.

References

Quantum states of polaritons

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We study how microcavity polaritons can be used to embed quantum information. Namely, we study their capacity to support entanglement and store information in the few particle limit. We describe the polaritons as particles resulting from the strong interaction between cavity photons \( a \) and excitons \( b \) through the Hamiltonian \( H = \hbar \omega_a a^\dagger a + \hbar \omega_b b^\dagger b + g (a^\dagger b + ab^\dagger) \) and study various quantum states that can be realized in pure or mixed form \( \rho \). Some typical configurations of interest are shown in Fig. 1, including “classical Rabi oscillations” (a) and genuinely quantum, but to date unobserved, states (c–e).

We use the popular criterion of Peres [2] to quantify entanglement through the negativity [3], defined as \( \mathcal{N}(\rho) = (1 - \|\rho^{1/2}\|_1)/2 \). We find that, at resonance, polaritons maximize the entanglement up to 22 particles, beyond which mixtures are to be favored, as is also the case out of resonance where equal distribution of lower and upper polaritons are maximized. We also discuss the dynamics of excitation of such states and study their fidelity in the course of their dynamical evolution, finding that while the lifetime of Rabi oscillations can be increased by a reservoir, as was recently predicted [4], the corresponding quantum state is on the other hand quickly spoiled, casting doubt on the usefulness of polaritons for quantum information processing at the time of writing, while classical applications are booming [5]. We discuss the prospects for useful QIP with polaritons in the near future.

Fig. 1. Glauber trajectories for several states: a) Coherent state of photons \( |\alpha,0\rangle \); b) Coherent state of polaritons \( |\alpha,0\rangle \); c) Superposition of coherent states \( |\alpha,0\rangle + |0,\alpha\rangle \); d) Cat state \( |\alpha,0\rangle + |-\alpha,0\rangle \); e) Polariton Fock state \( |5,0\rangle \). In all the coherent states, we have used \( |\alpha|^2 = 5 \). The normalization factors are different in each of the superpositions in c and d, but are irrelevant for the description.

References
Exciton-photon correlations in Bose-Einstein condensates of exciton-polaritons

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Exciton-polaritons are two-dimensional half-light half-matter quasi-particles with a bosonic statistics. Each individual polariton can be described as a superposition state of an exciton and a photon. One can argue that the polariton wave function collapses to the exciton or the photon state once the measurement is done. Alternatively, following the statistical interpretation of superposition states, exciton-polaritons can be interpreted as chains of transmission acts between excitons and photons. This would imply that an exciton-polariton spends some time as an exciton and some time as a photon. This model implies the existence of some hidden parameter: the rate of stochastic exciton-photon and photon-exciton conversion $1/\tau_{xc}$. We show that doing exciton-photon correlation measurements on Bose-Einstein condensates of exciton-polaritons one can distinguish between two above interpretations of superposition states. In this way, studying exciton-photon correlators one may seek to confirm or refute the basic postulates of quantum mechanics. We discuss several possible experimental configurations which give access to these correlators, including the photocurrent-photoluminescence and Kerr rotation-photoluminescence correlations. We have developed a model based on the Boltzmann-master equations for the probabilities to find given exciton and photon occupation numbers is a polariton condensate. We introduce stochastic exciton-photon transformations characterized by a rate $1/\tau_{xc}$ into the model and study exciton-exciton, photon-photon and exciton-photon correlators as functions of this parameter. We show that the second order photonic coherence function $g_{2}(0)$ deviates from 1 for a coherent condensate and tends to 4/3 with the increase of the rate $1/\tau_{xc}$. The corresponding exciton-exciton correlator behaves similarly. Meanwhile, the exciton-photon correlator $g_{2}(0)$ decreases with the increase of $1/\tau_{xc}$ having its saturation value at the level of 2/3. We interpret these results by mixing of lower and upper polariton branches induced by the stochastic exciton-photon conversions. We find also that the mean energy of the condensate varies from the low polariton branch to the bare exciton (photon) energy with the increase of $1/\tau_{xc}$, while its variance approaches $\sqrt{2/3}$ of the Rabi splitting. Clearly, exciton-photon correlation measurements represent a worthy experimental technique giving access to the internal structure of many-body light-matter condensates.
Single-Polariton Optomechanics

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Following the advances of theoretical and experimental quantum optomechanics and cavity or circuit quantum electrodynamics (cQED) we present here the theoretical study we undertook on a hybrid system coupling a cavity mode, an artificial two-level atom and a mechanical resonator [1,2].

We present the diagonalization of the corresponding Hamiltonian and obtain analytical expressions for the eigenvectors and eigenvalues of the Hamiltonian. We show that the system should no longer be treated in terms of atom, cavity and mechanical excitations but rather in terms of hybrid atom-cavity-mechanics polaronic excitations.

We study the dynamics and stationary statistics of the system under coherent and incoherent pumping of the Jaynes-Cummings atom-cavity states. The system then displays resonant cooling or amplification of mechanical motion and non-classical statistics of the mechanical resonator.

![Conceptual illustration of a system combining cavity quantum electrodynamics and optomechanics.](image)

Figure 1: Conceptual illustration of a system combining cavity quantum electrodynamics and optomechanics.

References

Ring-shaped polariton condensates

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Condensation of exciton polaritons in quantum states composed of concentric rings is observed when exciting cylindrical pillar GaAs/AlGaAs microcavities non-resonantly by a sharply focused laser beam at the center of the pillar. The number of rings depends on the pumping intensity and the pillar size, and may achieve 5 in the pillar of 40 µm diameter. Breaking the axial symmetry when moving the excitation spot away from the pillar center leads to transformation of the rings into a number of bright lobes corresponding to quantum states with nonzero angular momenta (see Figure). The number of lobes, their shape and location are dependent on the spot position. The spatial coherence of the ring emission as well of the lobes emission is verified by interferometry measurements. The out-of-equilibrium condensation of polaritons in the states with different principal quantum numbers and angular momenta is described with a formalism based on Boltzmann-Gross-Pitaevskii equations accounting for repulsion of polaritons from the exciton reservoir formed at the excitation spot and their spatial confinement by the pillar boundary.

![Image of polariton condensates](image_url)

Figure: Experimental (a – d) and calculated (e – h) real-space images of the polariton condensates in the 40 µm pillar at different shifts of the excitation spot to the right from the pillar center. The shift is equal to 0 (a, e), 5 µm (b, f), 10 µm (c, g), and 17 µm (d, h). Pumping power $P = 1.5P_{th}$, $T = 3.5$ K.
A Polariton Condensate in a Photonic Crystal Potential Landscape

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Exciton polaritons are an ideal system to study collective behavior of macroscopic coherent quantum states in a solid state environment as they fulfill a range of important prerequisites. The possibility to engineer polariton trapping potentials has triggered the interest in using polaritonic systems to simulate complex many-body phenomena, such as the physics of high-temperature superconductors, graphene, or frustrated spin lattices.

Here, we employ a technology that enables deep (several meV), potentially tunable trapping in any 2D geometry without affecting the favorable polariton characteristics. The traps are based on a locally elongated microcavity which can be formed by standard lithography.[1] We observe polariton condensation under non-resonant pumping in single traps and photonic crystal lattice arrays. In the latter structures, we observe pronounced energy bands, complete band gaps, and the spontaneous condensation at the M-point of the Brillouin zone.

![Figure 1](image)

Figure 1: (a) Scheme of a square lattice of 0D-polariton traps (2 µm diameter, 3 µm lattice constant). The sample consists of a AlAs-λ/2-cavity microcavity with 37 (32) bottom (top) AlGaAs/AlAs-DBR-mirrors. In the trap area the cavity layer is elongated by several nanometers which results in an overall trapping potential of ~ 5 meV. (b) Resulting band structure (false color plot) featuring a full band gap between the X and M-point of the brillouin zone. The band structure can be modelled with realistic parameters (black lines).

References

Heralded Phonon Entanglement in Photonic Crystal Cavities

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Cavity optomechanics [1] has demonstrated a spectacular theoretical and experimental development in the past decade and is now envisioned as one of the most promising routes to produce nonclassical states of macroscopic degrees of freedom mediated by an optical field. Such achievements would not only shine light on quantum decoherence at a fundamental level but could provide a long living information storage platform for potential quantum repeaters.

The recent prowess in the optimization of Si or InP based photonic crystal structures [2,3] allow now to combine outstanding quality factors of the cavity modes with localized vibration resulting in a sizeable optomechanical coupling. Such highly integrable and low footprint solid state structures lie among the best candidates for the future of quantum logic elements.

In that context, we propose a realistic heralding protocol for the preparation and readout of entangled phonons [4] within state of the art parameters measured in photonic crystal cavities and however easily extensible to other optomechanical systems. Our initial proposal relies on a cavity mode coupled to and a pair of mechanical modes and its sideband excitation. The mechanical entangled state is written through an antiStokes process supplemented by a single photon detection and, readout through the Stokes process producing a characteristic interference pattern at the cavity frequency.

Finally our procedure is not only extended to remote optomechanical systems but also to the formation of more complex entangled states of the W or NOON kind.

Figure 1: (a) Schematic representation of the system, (b) cavity and detector power spectrum, (c) reduced mechanical density matrix and (d) readout quantum interference pattern.

References
Plasmonic hot spots in nano-cavities

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Precise locating the strongest electric field in a metallic nanostructure still remains a great challenge because the field strength decays exponentially from the surface. The hot spot position for gold nanoparticles has been precisely located using surface enhanced Raman spectroscopy (SERS) by rationally choosing the probe molecules and excitation wavelengths and proposing plasmon driven catalysis applications in hybridized plasmonic gaps modes [1]. In this work we present a detailed study of the hot spots in nanocavities between two nanoparticles in several configurations varying the cavity length, we follow the hybridized plasmonic modes and examine how they can be modulated with incident light. Besides that we study the optical response of the plasmonic gaps when the distance between the particles reduces to even subnanometer region. For separations of a few Angstroms, in the quantum regime, optical tunneling can be produced modifying strongly the optics of the nanogap. We consider the classical effective model, known as Quantum Corrected Model (QCM), that has been introduced [2] to correctly describe the main features of optical transport in plasmonic nanogaps. We discuss in detail two cases, gaps between spherical nano-particles and cavities formed by one metallic nanoparticle surrounded by a dielectric shell and a metallic nano-shell built in within a matryushkas model

References


Polarisation reversal in spin-dependent polariton
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Spin-dependent properties of multicomponent exciton-polariton condensates have being probed in a number of recent experiments. Here we use the coupled Ginzburg-Landau equations describing the multicomponent exciton-polariton condensates to elucidate how the nonsymmetry in the polarisation of injected photons and thus polaritons affects the degree of the circular polarisation of the condensate. Depending on the pumping intensity, the degree of the polarisation splitting of the incoherent pump and the intrinsic splitting of linear polarisations present in most microcavity samples the multicomponent condensate can go into synchronised or desynchronised states of various degree of circular polarisation. Full bifurcation diagram of the system is obtained. In particular, it is shown that the polarisation reversal is possible.
Ultrafast control of light polarization exploiting polariton Rabi oscillations

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The coupled dynamics of exciton and photon in semiconductor microcavities produces light-matter oscillations (polariton Rabi oscillations) ruled by the time-dependent occupation of the eigenstates of the system (upper and lower polariton branches). Here, thanks to a comprehensive model of exciton-polariton Rabi dynamics and a digital holography technique for ultrafast spectroscopy of the polariton emission, we show how the time-dependent intensity and polarization of the emitted light can be precisely controlled by consecutive pulsed excitation of the system. Experimentally, the intensity of the emission is given by the photonic part of the polariton field, while the complete evolution of the system is described by a fundamental model of coupled bosonic fields (Fig. 1a). Interestingly, also the Poincaré sphere in the polarization basis can be spanned in time intervals as short as 10 ps, with a full control of the polarization dynamics on a femtosecond timescale (Fig. 1c).

Figure 1: a,b) Rabi dynamics of exciton-polaritons in the upper-lower and exciton-photon basis. c) Ultrafast measurements at different time (50 fs step) allow the representation of the polarization dynamics on the Poincaré sphere. d) The first pulse is circularly right-polarized (blue line) and the second pulse is circularly left polarized (red line).

References
The photoluminescence selection rules in superlattices

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A new breakthrough in the theoretical prediction of the emission spectrum of active superlattice structures is presented. Using the true intra-band eigenvalues $E_{\nu}^{e}$ and $E_{\nu}^{n}$, obtained from the finite periodic systems theory, and the inversion symmetries of the corresponding eigenfunctions $\varphi_{\nu}^{e,e}(z)$ and $\varphi_{\nu}^{n,n}(z)$, in the conduction and valence bands, new optical transitions selection rules for superlattices have been derived. Neither the reciprocal space nor the Bloch functions, valid only for infinite periodic systems [1], were used. Two of the selection rules, when the number of unit cells $n$ is even, are: $\mu = \mu' \pm 1$ and $n + n' = n$. Similar relations hold for $n$ odd. These rules reduce the number of possible transitions from about $N_{c}N_{v}^{2}$ to $N_{c}n/2$, where $N_{c} = n_{c}n_{v}$ is the product of the number of conduction and valence subbands. This means a reduction from about 600 to 30 transitions when the number of unit cells is 11. When the experimental resolution is low, a third rule, that picks up the leading order terms, reduces further the number of optical transitions to $n_{\mu} \leq N_{c}$, which, practically, coincides with those of the actual photoluminescence spectra. These results allow simpler photoluminescence calculations and will help to laser design. Excellent agreement with high resolution blue-laser photoluminescence [2] and previous transition index assignments [3] is found.

References
Excitonic properties of layer-by-layer grown thin and ultrathin quantum wells of II-VI semiconductors with control of the composition at the monolayer scale

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II-VI semiconductors and related alloys present very attractive properties for application in novel optoelectronic devices such as lasers, LEDs, photodetectors, solar cells, etc. The use of quantum wells (QW) in the active region of the devices allows the optimization and precise tuning of the optical properties of those heterostructures, however, many challenges related to the reduction of defects, interface mixing, accurate control of thickness and alloy composition and efficient doping remain. Thin (1.5 to 5 nm) and ultra-thin (1 to 4 compound monolayers) Zn$_{1-x}$Cd$_x$Se (0 ≤ x ≤ 1) QWs confined within Zn$_{1-x}$Mg$_x$Se barriers present very interesting excitonic properties (tunability in the full visible range, large excitonic energies, etc.). In this work, we will present results of the optical characterization of thin and ultra-thin QWs (UTQWs) of ZnCdSe; the observed features will be described in terms of their structural properties and growth conditions. To deposit the QWs we employ layer-by-layer growth techniques such as atomic layer epitaxy (ALE) [1] and submonolayer pulsed beam epitaxy (SPBE) [1, 2]. With these techniques, we are able to tune the composition for each individual monolayer of the QWs. The complete epitaxial heterostructure is elaborated using the mentioned growth methods in combination with molecular beam epitaxy (MBE). The peculiarities of the strong and well defined excitonic emission of (subnanometric) single and multiple UTQWs will be described and the results of a detailed study (theory and experiment) of the coupling/uncoupling of symmetrical and asymmetrical double UTQWs will be shown. Finally, a brief discussion of the fractional dimensionality of the UTQWs excitons will be presented.

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References

Structural and dielectric properties of a new lead-free ferroelectric BCTG ceramics
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Although the lead ferroelectrics (mostly based on PZT and PM-NPT) are playing a dominant
role in the ferroelectrics materials, their evaporation of harmful lead oxide during the
preparation causes a crucial environment problem. There is an increasing demand for lead-
free ferroelectric which are environmental friendly materials. Numerous compounds have
attracted much attention in both fundamental research and technological applications in order
to elucidate their promising properties. However, most potential lead-free systems like:
BaTiO 3 [1], NBT-NKT [2], NBT-BaTiO 3 [3], Ba(Zr,Ti)O 3 [4,5] and BCT [6,7] systems are
being developed for a wide range of applications especially for electrical and electronics
engineering. The effects of Tellurium addition on structural, electrical, and electrocaloric
properties of barium calcium titanate Ba0.8Ca0.2TiO 3 (BCT) are investigated. The
polycrystalline ceramics were prepared by solid state reaction method. X Ray diffraction has
allowed the identification of pure perovskite structure without secondary phase and
crystallized in tetragonal symmetry. The incorporation of Te- element in the BCT host lattice
(TeBCT) induced decreases of the Curie temperature and enhances the polarization. The
electrocaloric investigation of the prepared ceramics is carried out by indirect calculation of
ΔT given by thermodynamic equation analysis of P–E hysteresis loops at different
temperature. Promising electrocaloric strength coefficient, ΔT/ΔE, is obtained for (TeBCT)
twice higher than that one observed for pure BCT phase. The obtained value is higher as those
observed for lead-free ferroelectric materials reported so far.

References
Wang, H.
Marassi, Structural and dielectric properties of a new lead-free ferroelectric
Ba0.8Ca0.2Ti0.8Ge0.2O3 ceramics, Superlattices and Microstructures, Volume 71,
(2014), 162–167
Self-assembled 4N10In and 1N4In clusters in GaAs:(In, N)

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Semiconductors with isoelectronic centers actively studied now [1] are perspective materials for fabrication of arrays of the single photon emitters required for quantum computers. Among III-V semiconductors, GaAs doped with nitrogen is one of the most studied since the nitrogen dyads bound excitons [1]. However, nitrogen is the highly mismatched impurity in GaAs. Therefore, nitrogen dyads introduce the significant strains in GaAs:N. Such GaAs:N can be formed only under non-equilibrium growth conditions and should be in the thermodynamically unstable state with respect to the transformation of the dyads into isolated impurities. It is their serious disadvantage of GaAs:N. Self-assembling (SA) of 4B10Sb and 1B4Sb clusters considerably decreases the internal strains in GaAs:(B, Sb) was proposed as a way to solve this problem [2]. Here SA of 4N10In and 1N4In clusters in GaAs:(In, N) also decreases the internal strains is represented.

Co-doping with In and nitrogen transforms GaAs into GaAs-rich In_{x}Ga_{1-x}N_{y}As_{1-y} alloy of InN, InAs, GaN and GaAs. Self-assembling of both types of clusters decreases a sum of the free energies of the constituent compounds and strain energy of In_{x}Ga_{1-x}N_{y}As_{1-y}. 4N10In and 1N4In clusters are the empty tetrahedral nitrogen cells surrounded by In atoms and In tetrahedrons with the central nitrogen atoms, respectively. The conditions are considered from 0 °C to 800 °C in the dilute and ultra dilute limits for In and nitrogen, respectively. All or almost all nitrogen atoms are in 4N10In clusters from 0 °C to 800 °C in In_{x}Ga_{1-x}N_{y}As_{1-y} with contents x = 1 × 10^{-4}, y = 1 × 10^{-4} and x = 1 × 10^{-1} and in 1N4In clusters if x = 0.01, y = 1 × 10^{-4} and x = 1 × 10^{-2}, y = 1 × 10^{-2} in In_{x}Ga_{1-x}N_{y}As_{1-y} with x = 5 × 10^{-5}, y = 5 × 10^{-5}; x = 1 × 10^{-4}, y = 1 × 10^{-4}; x = 2 × 10^{-5}, y = 2 × 10^{-5}; x = 2 × 10^{-5}, y = 2 × 10^{-5} and x = 2 × 10^{-3}, y = 2 × 10^{-3} there both types of clusters. The portions of nitrogen atoms in the clusters depend on the content and temperature. The SA conditions were obtained by minimization of the free energy.

The nitrogen dyads bound excitons in GaAs:N [1]. Therefore, the formation of excitons in GaAs:(In, N) with self-assembled 4N10In identical clusters is highly probable. These results demonstrate that GaAs:(In, N) with the small In and nitrogen contents is the promising semiconductor for the fabrication of arrays of the single photon emitters with the same emission energy. If In_{x}Ga_{1-x}N_{y}As_{1-y} form under non-equilibrium conditions that the thermal treatment which is an effective method for redistribution of atoms [3] can be used for SA of the clusters.

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References
Highly Sensitive Room Temperature Infrared Hybrid Organic-Nanocrystal Detector

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The ability to integrate electronics with nano-crystals (NCs) allows one to utilize their unique quantum properties for future optoelectronic devices. In our work we combine a top down approach by using self-assembled organic monolayers with NCs, together with bottom up components. This approach can revolutionize classical devices incorporating supplementary quantum properties in them. Here we present a highly sensitive near-infrared light detector device based on InAs NCs acting as an optical gate on top of a high-mobility shallow two-dimensional electron gas channel. By using a very narrow channel, the device’s quantum efficiency can go as high as $10^5$V/W at room temperature, with a signal-to-noise ratio (SNR) that enables high sensitivity for very low photon power. The presented experimental results are compatible with those using simulation. Lastly, the route to advance to the single photon detection limit is discussed.

Figure 1: The hybrid organic NCs' detector, based on GaAs HEMT with NCs acting as a gate.

References
DESIGN OF A PRESSURE SENSOR WITH METAMATERIAL STRUCTURES

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Sensors pressure can be constructed by metamaterials, these in turn are building with thin wires and Split-ring resonators (SRR’s). If modify the geometry, dimensions and constituent materials of the SRR the metamaterial resonance frequency are changed. The control of these parameters can be used for practical applications such as the construction of sensors, notch filters and many other applications. In this work we evaluate a metamaterial pressure sensor. This sensor consists of a dielectric substrate loaded with thin wires and SRRs for which we analyzed the modification of the reflected coefficient when the cell dimensions inside the metamaterial structure are changed. We compared experimental results with an elementary expression for the calculation of pressure and we can identify the type of force exerting such pressure.

References


POSTER PRESENTATIONS

Self-assembling of carbon and Sn in Ge:(C, Sn)

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Co-doping with carbon and Sn transforms Ge into Ge-rich CxSn1−x substituted alloy. Self-assembling of 4C10Sn and 1C4Sn clusters decreasing the strain energy is preferential from the thermodynamics standpoint in the wide temperature and carbon and Sn content ranges. 1C4Sn clusters are Sn tetrahedrons with carbon atoms in their centres and 4C10Sn clusters are empty carbon tetrahedrons surrounded by Sn atoms. The formation of 4C10Sn clusters and self-assembling of 1C4Sn clusters are the competing processes. The self-assembling conditions of 4C10Sn and 1C4Sn clusters in CxSn1−x are represented from 0 °C to 800 °C and at the carbon and Sn concentrations 5×10−5 ≤ x ≤ 0.015 and 1×10−4 ≤ y ≤ 0.015, respectively. If carbon is a minority impurity than only 1C4Sn clusters should form. The temperature of the occurrence of 1C4Sn clusters depends only on the Sn content and grows with its increase. Both types of clusters with the strongly preferential formation of 4C10Sn clusters over 1C4Sn clusters should occur if the impurity concentrations are almost equal or if Sn is the minority impurity.

The electronegativity of carbon is considerably larger than that of Ge and Sn. Accordingly, isolated carbon atoms and 1C4Sn clusters are candidates for the formation of exciton traps in CxSn1−x. Self-assembling of 1C4Sn clusters reduces considerably the lattice strains around carbon atoms. It should lead to the increase of the binding energy of the excitons. Therefore, the excitons bound on 1C4Sn clusters should have the larger binding energy than those on isolated carbon atoms and, accordingly, such clusters are more promising for the formation of exciton traps. It is well known that isoelectronic impurity complexes form the exciton traps more suitable for device applications than those of isolated impurities. Accordingly, 4C10Sn clusters should be more promising objects than 1C4Sn clusters to bind excitons. To conclude, Ge:(C, Sn) is the perspective candidate for fabrication of arrays of the single photon emitters.

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Self-assembling of impurity clusters in AlN: (Ga, $B^V$, $C^V$), ($B^V$, $C^V$ = P, As; P, Sb: As, Sb)

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Arrays of identical single photon emitters are expected to play an important role in quantum information technology for fabrication of quantum computers which would dramatically improve computational power [1]. The self-assembling conditions of two type arrays of identical isoelectronic impurity clusters consisting of Ga and two anion impurities in AlN: (Ga, $B^V$, $C^V$), ($B^V$, $C^V$ = P, As; P, Sb: As, Sb) are represented. Such doping transforms AlN into AlN-rich Ga$_x$Al$_{1-x}$N$_{1-y}$, quinary substitutional alloy of GaA$y$, GaC$y$, GaN, AIB$^V$, AIC$^V$ and AlN. The self-assembling conditions are considered from 0 °C to 1000 °C in the dilute and ultra dilute limits for the cation and anion impurities, correspondingly. In such alloys self-assembling of $B^V$4Ga and $C^V$4Ga tetrahedral clusters is profitable from the thermodynamics standpoint. The preferential GaB$^V$, GaC$^V$ and AlN bonding over GaN, AIB$^V$ and AIC$^V$ one is the cause of self-assembling of $B^V$4Ga and $C^V$4Ga clusters. This preference is due to the very large enthalpy of formation of AlN which is the greatest among those of A$^{11}$B$^V$ semiconductors.

The cluster occurrence temperature depends on the Ga content and increases with its enlargement. 1P4Ga and 1As4Ga cluster occurrence temperatures are equal, correspondingly, to 797 °C and 736 °C at Ga content $x = 2%$ and at P and As contents $y = z = 0.01\%$ in AlN: (Ga, P, As). For 1P4Ga and 1Sb4Ga these temperatures are equal, correspondingly, to 976 °C and 736 °C in AlN: (Ga, P, Sb) at the same impurity contents. The 1As4Ga and 1Sb4Ga cluster occurrence temperatures are equal to those in AlN: (Ga, P, As) and AlN: (Ga, P, Sb), correspondingly, at Ga content $x = 2\%$. The temperature ranges between the cluster occurrence and self-assembling completion when all anion impurities are in clusters are small. It allows us to choose the self-assembling conditions under which the desired density of impurity clusters should be formed in the wide temperature and impurity composition ranges.

1P4Ga, 1As4Ga and 1Sb4Ga clusters are the identical ~1 nm low band gap objects with compositions GaP$_{0.25}$N$_{0.75}$, GaAs$_{0.25}$N$_{0.75}$ and GaSb$_{0.25}$N$_{0.75}$, respectively, embedded in the wide band gap (AlN-rich) matrix. Therefore, the formation of excitons bound on the clusters is highly probable. Furthermore, the clusters should be in the same strain field due to the contents in the ultra dilute limit of the highly mismatched impurities. Accordingly, the internal strains caused by self-assembling of the clusters cannot lead to an undesirable broadening of the luminescence width. Thus, AlN: (Ga, P, As), AlN: (Ga, P, Sb) and AlN: (Ga, As, Sb) are promising candidates for fabrication of arrays of single photon emitters with two emission energies.

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References

Non-equilibrium transport and spin dynamics in single-molecule magnets

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Single-molecule magnets (SMM) coupled to ferromagnetic or nonmagnetic leads are promising candidates for solid state implementation of quantum information protocols [1]. The exchange coupling between electrons tunneling through unoccupied molecular orbitals and the localized molecular spin $S$ allows the electrical switching of the latter. A key ingredient here is the magnetic anisotropy parameter $D$. We present a theoretical description of the time-dependent transport through SMM in the framework of the Generalized Master Equation (GME) method [2].

Our approach allows the calculation of transient charge and spin currents through the molecule beyond the Markov approximation. We analyse the currents associated to specific states of the system in order to get a detailed picture of the evolution of the system under the applied bias. We also investigate the possibility to read the dynamics of the molecular spin from transient current measurements. The steady-state transport properties and molecular spin relaxation are also considered and compared to previous results [3,4].

Finally we discuss the effect of time-dependent signals applied at the contacts between the molecule and particle reservoirs, particular attention being payed to the quantum turnstile setting [5,6] which we propose as a new way to manipulate molecular spins. In particular we show that for ferromagnetic leads with antiparallel spin polarizations the turnstile protocol allows the stepwise writing and reading of molecular states with well defined spin $S_z$. The efficiency of the turnstile operation as a function of the bias is also addressed.

References

The polaritonic spectrum of 2D photonic crystals based on uniaxial polar materials

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We investigate the dispersion relations of 2D photonic crystals made of cylindrical rods of uniaxial polar materials that exhibit transverse phonon-polariton excitations [1]. The rods are embedded in a dielectric background. The photonic properties are obtained with the use of the finite-difference time domain (FDTD) method and the auxiliary differential equation (ADE) technique [2]. The anisotropy of the dielectric function is explicitly considered using an empirical approach that gives different weights to contributions of the parallel (z) and transversal (⊥) polaritonic relations. The effective dielectric function is then expressed as \( \varepsilon(\omega) = \varepsilon_z(\omega) + \alpha_{⊥} \varepsilon_{⊥}(\omega) \). Different sets of values of the coefficients \( \alpha_{z} \) and \( \alpha_{⊥} \) have been considered. The frequencies of the allowed electromagnetic modes are determined as the local maxima of the spectral analysis using a fast Fourier transform (FFT) [3].

\[ \omega a / 2 \pi c \]

**Figure 1:** Dispersion relation for the transversal magnetic (TM) modes in a two-dimensional photonic crystal with squared lattice cell, and made of AlN cylinders in air. The ratio of the lattice constant and the cylinder radius is taken as 18/5. In addition, \( \alpha_{z} = 0.9 \), and \( \alpha_{⊥} = 0.1 \).

References

The polaritonic spectrum of 1D photonic crystals based on uniaxial polar materials

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The properties of the polaritonic modes that appear under oblique light incidence in 1D superlattices made of photonic materials are studied [1]. The investigated systems result from the periodic repetition of quasiregular Rudin-Shapiro multilayer units. It is assume that the structure consists of both passive –non-dispersive- layers of constant refraction index and active layers of uniaxial polar materials. In particular, we consider III-V wurtzite nitrdes. The optical axis of these polaritonic materials is taken along the growth direction and the anisotropy of their dielectric functions is empirically introduced by a suitable weighting of the parallel (along c-axis) and perpendicular contributions. Maxwell equations are solved using the transfer matrix technique for all admissible values of the incidence angle [2].

Figure 1: Dispersion relation of the TM modes in a 1D photonic crystal with an elementary unit cell given by the quasiregular ordering of dielectric layers given by a third-order Rudin-Shapiro –four letter- sequence. Two different values of the incidence angle are considered. Numerical results correspond to a system with air in the layer A (ε_A=1.0 and μ_A=1.0), two different uniaxial polar materials in the B (AlN) and C (InN) and, in the layer D we consider a non-dispersive material with ε_D=3.0 and μ_D=1.0. All layer widths were set equal to 1 μm. Here \( \nu_{\text{i,TT}}, \nu_{\text{i,LT}}, \nu_{\text{p,TT}}, \nu_{\text{p,LT}} \) (i=B,C), correspond to the characteristic transversal (T) and longitudinal (L) phonon frequencies of the uniaxial material (p=perpendicular, ||=parallel).

References
Charge distribution instability in impurity doped nanocone

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Currently there is significant interest in the theoretical study of semiconductor nanowires (NWs) since they are considered as one of the most promising building blocks for the design of a variety of photonic devices. Light emitting diodes, photodetectors, solar cells and solid-state sources of single-photons are some of the potential applications of NWs. Today, the ability to control the growing of nanowires in terms of their composition and morphology has become possible fabricating 1D nanostructures such as nanowire superlattices (NWSLs) [1] and nanocones [2]. One can expect that these novel configurations of NWs open up new opportunities for controlling their energy spectra and the charge distribution within them by varying their composition or geometry. To explore such possibility, we study the transformation of spectral properties of impurity doped nanocone provoked by the change of the impurity position, the dimensions of the structure and the intensity of the electric field applied along the symmetry axis. A simple method for solving the corresponding Schrödinger equation is proposed for, which allows us to calculate the energies and wave functions and energies of the lower states. Our results reveal that the gap between energies of the ground and first excited states and the dipole moment induced by the external electric field are very sensitive to the variation of donor position. A special interest presents the case of the donor impurity location over upper surface of the truncated cone, when the interplay between the structural confinement and the electron-donor attraction results in a formation of the first excited state with a giant electric dipole moment and very small gap. We show that the dipole moment of such system can be changed drastically by jump under the external electric field. We believe that our approach may be extended to study the spectral and magnetic properties a variety of few particle systems confined in nanotubes with different profiles, for which more rigorous methods require extensive numerical calculations.

![Diagram of an impurity doped nanocone](image)

Figure 1: Scheme of an impurity doped nanocone.

References
Stark effect in magneto-exciton confined in GaAs/AlGaAs nanotube

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Abstract

The excitonic states of electron-hole pair in a circular rolled up nanotube semiconductor quantum well in the presence of the magnetic and electric fields applied along the symmetry axis are studied theoretically, making emphasis in the analysis of the Aharonov-Bohm effect. The Fourier series expansion technique and finite element method have been used in order to solve the corresponding Schrödinger equation. Using the material constants appropriate to GaAs/AlAs semiconductor the exciton energies as functions of the external and the magnetic field, and of the nanotube radius have been calculated.

We show that the Aharonov-Bohm oscillations of the exciton energies as functions of the external magnetic field, originated by the electron-to-hole tunneling through barriers provided by the Coulomb potential, are more pronounced in nanotubes than those in rings. We ascribe this fact to the larger averaged separation between the electron and the hole in 2D structures than one in the quasi-one-dimensional ring. Our calculations reveal that it is possible to increment this separation by applying an electric field along the symmetry axis increasing in this way the electron-to-hole tunneling current, induced by the external magnetic field making more apparent the Aharonov-Bohm oscillations of energy levels.
Studying the electronic and optical properties of lignosulfonates for the development of new materials

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The lignosulfonates (LS) are lignins in sulfonated form obtained from the residual sulfite liquors, a byproduct of the cellulose extraction in the paper pulp and wood industry. The usefulness of LS lies in their wide spectrum of applications that includes additive, dispersant, and adhesive agents, used in fields from food processing to fertilizers, and even in the fabrication of ion exchange membranes. Given that LS can be manufactured with relative easiness and rapidness, and their molecular structure can be manipulated to obtain a wide range of molecular properties, sizes and reactivity, these substances are widely used as transport agents in the cosmetic and pharmaceutical industry, in the development of new drugs and as molecular carriers in the treatment of sanitary issues. In this work we have performed an structural, electronic and optical characterization of ammonia, sulfur, calcium and sodium LS in acid and basic aqueous mediums aiming to understand the behavior, properties and new possible applications of this substances, in fields like organic semiconductors, molecular carriers and as auxiliary agents for the treatment of residual waters. This study is developed using the semiempirical methods AM1 and PM3 of the DNO (Neglect of Differential Overlap) family for the structural characterization and the ZINDO/C1 method for the electronic and optical study.
Effect of a High Intensity laser beam on impurity binding energy in a nanocone

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We report the theoretical results obtained by studying the effect of an intense high frequency laser on the ground-state binding energy of a hydrogenic impurity located on the axis of a GaAs nanowire with nanocone shape. The results were obtained using the trigonometric sweep method and variational scheme in the effective mass approximation framework. The binding energy is determined according to the position of the impurity along the axis of the wire and the intensity of the laser field. The results agree with previous results obtained in similar systems.

Keywords
Nanocone, Quantum wire, Binding energy, Donor impurity, Intense laser-field
Structure and Morphology of InGaAs thin films grown by Magnetron Co-Sputtering on Different Substrates

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In recent years there has been a strong interest in obtaining semiconductor III-V ternary as a thin film on different substrates, which would allow its use in different fields of technology. Some of the most used substrates are: Silicon (Si), germanium (Ge), gallium arsenide (GaAs) and transparent substrates (glass). In this work we focus on obtaining InGaAs thin films deposited on different substrates: Si (100), GaAs (100) and Glass by r.f. magnetron co-sputtering using targets of GaAs and In. The sputtering power of Indium target was varied to obtain thin films with different stoichiometry, the other parameters were hold constant during growth. The samples presented a preferential growth along of (111) which was confirmed from X-ray diffraction. Likewise, vibrational modes were studied by Raman spectroscopy. The morphology of each of the samples showed significant change as shown in Figure 1. Finally, Chemical composition was determined from measurements energy dispersive spectroscopy; results were correlated with values obtained from the displacement in 2 theta in x-ray, and band gap shift at lower energies.

![Image of AFM topography images](image_url)

Figure 1: AFM topography images for InGaAs thin films deposited on different substrates.
Optical properties of graphitic carbon nitride from
time-dependent density functional theory

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In this work we have studied the optical properties of the new photocatalytic graphitic compounds g-C₃N₄, namely g-h-heptazine and g-h-triazine. First, we have optimized the lattice parameters by means of van der Waals density functional theory (vdW-DFT) [1], which includes nonlocal, long range electron correlations that are responsible for van der Waals dispersion forces. Second, we have calculated the quasiparticle energies by the non-self-consistent GW approximation (G₃W₃) [2], where the Green function G₀ and the screened Coulomb kernel W₀ are calculated using the vDW-DFT Kohn-Sham eigenvalues and eigenfunctions of the ground state structures. Finally, the dielectric function and the absorption coefficient of g-C₃N₄ are calculated by the random phase approximation (RPA) and time-dependent density functional theory (TDDFT) with a new parameter-free approximation for the exchange-correlation kernel (Bootstrap kernel) [3] on top of the vDW-DFT electronic structure. It is found that due to the interlayer vdW bonding and intralayer covalent bonding there is a huge anisotropy of the optical properties, where the main absorption peaks are located for g-h-heptazine around 5 eV along the principal intralayer directions and 17 eV along the interlayer direction; whereas for g-h-triazine these peaks are located around 5.5 eV and 18 eV. It is also observed that excitonic peaks are absent in these materials.

References

Polariton molecules based on tunable open microcavities

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Exciton-polaritons attract significant attention due to their strong Kerr-type nonlinearity inherited from their excitonic fraction. This property enables interesting polariton quantum fluid phenomena predicted in photonic lattices [1]. In this paper, we present a novel microcavity structure which enables strong submicron lateral confinement of polaritons (and hence strong interactions), achieved for the first time using an open cavity device and only a single quantum well as the active region. Our system consists of two distributed Bragg reflectors (DBRs) attached to separate nanopiezopositioners, which allows free tuning of cavity length and the tilt angle between the mirrors [2]. Polariton molecules can be constructed by partially overlapping two circular-shaped top concave mirrors, as illustrated in Figure 1(a). In our experiment, bonding (B) and antibonding (AB) modes were observed in coupled open cavities. By tuning the tilt angle of the bottom DBR, the energy difference between the two cavity modes can be varied so that they can be coupled and decoupled in a controlled fashion (Figure 1 b-e). Strong exciton-photon coupling is also demonstrated in such systems, where the exciton/photon fraction has a dramatic influence on the B and AB coupling strength, with the B and AB splitting reduced by increasing exciton fraction. Such microcavity coupling provides an efficient way to freely control the physical properties of polariton molecules and construct lattice polaritons with strong on-site interactions.

![Diagram](attachment:image.png)

Figure 1: a) schematic cross-section of a coupled open cavity. b) Energy separation between B and AB modes as a function of tilt angle of the bottom mirror. Images of optical modes at tilt angles of bottom mirror $-0.1^0$ (c), $0^0$ (d) and $0.076^0$ (e).

References
Optical properties of a multibarrier structure under intense laser fields

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Using the modified transfer method technique [1,2] and within the effective mass approximation, the energy spectrum and the wave functions are investigated in a varied spaced biased multibarrier structure in GaAs/Ga1-xAlxAs taking into account the effects of nonresonant intense laser fields. We calculated the optical properties from the susceptibility using nonperturbative formalism and paying special attention of the resonance widths, because it is well known that these dephasing times have influence on the intersubband optical process [3].

We study the changes in the optical absorption coefficients and refraction index induced by the separation in the energy levels for several values of the dressing laser parameter and for some specific values of the applied electric field along the growth direction of the heterostructure. It is concluded from our study that the peaks in the optical absorption spectrum are redshifts or blueshifts as a function of the laser parameter and the electric field and these parameters could be suitable tools for tuning the electronic and optical properties of superlattices.

References

Photonic properties of a square lattice of dielectric hollow rods embedded in a metallic background

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Photonic modes of a square lattice composed by dielectric cylinder hollow rods embedded in a metallic matrix were characterized. Numerical results are obtained by using the well known plane wave expansion method in the case of TM polarization, where no plasmon modes are present. Theoretical data are presented as functions of the inner and outer radii, $R_1$ and $R_2$, respectively, showing a widening of the band-gaps by increasing $R_1$. In order to evidence that behavior, the photonic gap-map is presented as a function of the inner radius. Also, we present the Photonic band structure for several configurations in order to study the behavior of the cut-off frequency as a function of the filling fraction of the unit cell.

References


Electron-related Raman scattering in dilute nitride heterosystems

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In this work, we study the electron-related Raman scattering in cylindrically shaped quantum dots (QDs) made of the III-V semiconductor heterosystem GaAs/Ga₁₋ₓInₓAs₁₋ᵧNᵧ. It has been shown that the Raman scattering in QDs has a strong dependence on the size and geometry, the presence of external probes as electric and magnetic fields and hydrostatic pressure [1]. Such studies were performed for GaAs-based structures; but the dilute-nitride-based QDs seem to have not been considered so far. Thus, the aim of our work is to investigate the influence of In and N contents as well as of the dot’s dimensions on the Raman differential cross-section on the basis of the calculated electron energies and wavefunctions. For that purpose, we use the band anti-crossing model within the effective mass approximation in order to take into account the influence of the deep acceptor states on the conduction band states in the quaternary alloy of the quantum well region. Besides, the strain effects are introduced using the information on valence band alignment provided in the so-called model solid theory [2]. We show that it is possible to control the peak intensity and the frequency shift by changing the In and N molar fractions and the dot’s geometry.

References
Dynamics of the Energy Relaxation in a Parabolic Quantum Well Laser

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In recent years, research into coherent light sources based on bosonic systems (known as bosers, or bosonic lasers) has seen a rapid increase. These bosers are capable of operating in the stimulated emission regime like a traditional semiconductor laser, but unlike the fermionic counterpart they do not always require an inversion of population to lase and the final state population of the system is able to stimulate relaxation. One particularly promising structure for the basis of a boser is a superlattice where excitation is mitigated by exciton-polaritons.

We build upon the idea of a bosonic cascade laser BCL described by Liew et al., which a bosonic device analogous to the quantum cascade laser (QCL). The BCL uses a similar cascade mechanism to that of the QCL in order to achieve amplification of radiation, however, unlike the QCL which uses multiple adjacent quantum wells (QWs) as the cascade ladder, the BCL cascade occurs between equidistant excitonic levels in a single parabolic well.

We report the realisation of such a parabolic quantum well (PQW) sample, and present the characteristics of a PQW sample with and without a microcavity. We experimentally demonstrate that PQWs are capable of acting as non-resonantly excited polaritonic lasers, as well as being capable of emitting light via the bosonic cascade mechanism. Finally we contrast the optical PQW relaxation photoluminescence (PL) measured from the samples in the BCL scheme to that which is predicted by the rate equations applied to an excitonic cascade system operating in the weak coupling regime and find strong agreement between the theoretical model for ground state emission from a PQW with what is observed experimentally.

References

Faraday rotation in metamaterial-anisotropic photonic superlattices

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We have performed a theoretical analysis of the negative refractive effects on the Faraday rotation in photonic superlattices made up of alternating left-handed material (LHM) and anisotropic material slabs. Numerical results are obtained by using the scattering-matrix technique. Theoretical predictions are found for Faraday rotation, ellipticity, and polarization conversion. As well as, we have considered the case of oblique incidence for both TE and TM incident light, in which case we may study the combined plasmon-polariton and negative refractive effects on the Faraday rotation.

We are grateful with the Colombian agencies COLCIENCIAS and CENM-UNIVALLE. J.R. M-S is supported by a Post Doctoral Fellowship grant of the Programa Nacional de Pós-Doutoramento (PNPD/CAPES) at the Universidade Federal de Alagoas (UFAL) through the Project Nr. 02727/09-9.
MAGNETIZATION AND OPTICAL PROPERTIES OF ONE AND TWO PARTICLES IN QUANTUM RINGS

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We study the spectral properties such as magnetization an optical properties of one-two particles in a non-uniform crater-shaped quantum dot that is modelled by a thin layer, whose thickness increases linearly with different slopes in different radial directions between the central hole and the outer border. We show that in the adiabatic limit, when the crater thickness is much smaller than its lateral dimension, the one-particle wave functions of an electron and a hole can be found exactly in an analytical form and they subsequently can be used as the base functions in framework of the diagonalization method to study the energy levels and the magnetization of one and two-particles confined in a non-uniform quantum ring with a magnetic field applied along of the grown axis. It is found a manifestation of the Aharonov-Bohm oscillations of the lower energy levels of the electron and the magnetoexciton, in a crater in spite of the presence of both the electrostatic attraction between carriers and the structural non-uniformity. We attribute this result for the magnetoexciton to the tunnelling of the particles, induced by the magnetic field, through the potential barriers with the respect of the particles independent rotation generated by the electron-hole interaction and the additional confinement due to the structural non-uniformities, respectively.

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Dependence Of Number Defect With The Modes In 1D Photonic Crystals

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In this article, we investigate how the photonic band gaps and the variety of band dispersions of photonics crystals can be utilized for various applications and how they further give rise to completely novel optical phenomena. A theoretical analysis of the properties of the defect modes in a one-dimensional defective photonic crystal is given. The theoretical reflectance or transmittance spectrum can be directly calculated with a matrix formalism methods in two defective photonic crystal stacked in symmetric and asymmetric geometries are considered. The defect modes are investigated by the calculated wavelength-dependent transmittance for both TE and TM waves. It is found that there exists two defect mode within the photonic band gap in the asymmetric photonic crystals. There are, however, two defect modes on the angle of incidence are illustrated. Based on the calculated transmission properties in a defective photonic crystals, the properties of the defect modes for the asymmetric and symmetric structures have been theoretically investigated. In a asymmetric structure, there is a single defect mode inside the photonic crystal. The peak height is strongly dependent on the angle of incidence for both TE and TM waves. In a symmetric one, we find that there are two defect modes. The peak height of these two modes are independent of the incident angle. The effect of the incident angle is to shift the defect positions to the shorter wavelengths. Additionally, the effect of defect thickness on the number of defect modes is also examined. The analysis on the defect modes provides useful information for the design of a narrow band transmission filter based on the one dimensional photonic crystals.

References


Plasmon enhanced Raman scattering by hybrid nanotube systems

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A quantum electrodynamics theory of the resonance Raman scattering is developed for a hybrid quantum system of a two-level dipole emitter, two-level system (TLS), coupled to an inter-band plasmon resonance of a carbon nanotube (CN). This resonance Raman scattering is a manifestation of the general Surface Enhanced Raman Scattering (SERS) effect received much of attention recently due to a very broad range of its applications in nanophotonics, biochemistry, and medicine[1]. Here, the SERS effect comes about as a near-field effect, to which strong local-field enhancement occurs due to the inter-band plasmon excitation when the TLS is located near the CN surface and its transition energy matches the CN plasmon resonance energy[2]. The effect is rigorously calculated using the scattering matrix formalism (e.g., Ref.[3]) for the hybridized (coupled) four-level system "TLS+CN plasmon resonance". The entire scattering process consists of the system excitation by an external radiation, followed by the CN plasmon emission/absorption and de-excitation via the Raman photon emission. Raman cross-section derived covers both weak and strong TLS-plasmon coupling, and shows a dramatic increase ~10^4 in the strong coupling regime. The effect may be used to detect individual atomic type objects trapped (physisorbed, not chemisorbed) near CNs. More advanced applications, which require further theoretical development, may include highly efficient CN based SERS substrates for single molecule/atom/ion detection, precision spontaneous emission control, and manipulation.

Figure 1. Calculated Raman intensities for TLS coupled to a nanotube inter-band plasmon resonance. Typical parameter values are used for \( X, \Delta X, x_1 \) and \( x_2 \) to represent the Rabi splitting energy, the plasmon resonance width (in eV), the incoming and outgoing radiation energies, respectively. The TLS-plasmon coupling strength is represented by the ratio \( X/\Delta X \).

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References
A resonant tunneling diode based on Al$_{1-x}$Ga$_x$As/GaMnAs/AlAs double-barrier asymmetric structure

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The characteristic feature of GaMnAs heterostructures such as high-quality single crystallinity, flat interfaces, and good compatibility with III-V heterostructures are quite attractive and have motivated us to investigate nano-devices with spin effects such as the $k^2$-Dresselhaus and Rashba, low the model non-rectangular barriers type Pöschl-Teller. The results obtained for the polarization of spin are in function of the energy applied to electron, the well width; addition analyzed spin-polarized current the function applied bias. This allows suggest that these features could be engineered in the fabrication of tunable spin-dependent electronic devices such as resonant tunneling diode (RTD).

References
Quantum Chaotic Encryption on a NMR Computer

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Fractional Fourier transform of order $\alpha$ (FrFT)[2, 3] has recently become a central element in signal processing and it is crucial in, e.g., implementing Pseudopolar and Radon transforms [1]. We extend the applicability of the FrFT to the context of image encryption. In particular, we generalized the quantum version of the Baker’s map [5] to the case of continuous time (rotations by an arbitrary angle $\alpha$) and used it to encrypt images. We propose an implementation of the continuous-time quantum Baker’s map on a NMR quantum computer by making use of quantum gates using to compute the coefficients of the fractional Fourier transform [4]. The quality of the encryption process is verified by the correlation coefficient of adjacent pixels, which is contrasted to the correlation coefficient from the application of the discrete-time version of the Baker’s map. Although the FrFT operator forms a semi-group parametrized by the angle $\alpha$, we found that the continuous-time does not form a semi-group in $\alpha$. We discuss how to take advantage of this to enhance the level of ciphering.

References


Dynamical characterization and entanglement generation in a coupled ion-NEM system

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The first proposal of a coupling ion-NEM was made by Tian and Zoller [1] with the ions immerse in mesoscopic traps, and where suspended nanomechanical resonators played the role of electrodes of the trap with its own degrees of freedom. Hensinger et al [2] showed that a single trapped ion could be used to test the quantum nature of a mesoscopic mechanical oscillator. This simple system shows a similar behavior to that of a quantum dot coupled to a photonic molecule associated with two cavities [3]. In order to achieve the necessary coupling between the vibrational mode of the ion with the mode of the oscillator, we applied an external laser and as a result both modes end with a small detuning $\Delta \approx 0$, and the ions degrees of freedom in the Lamb-Dicke regime. Two main features emerge from this system: the first one is the ability to probe the internal degrees of freedom of the ion, such as the electronic mode, using an indirect coupling to the NEM. This proves to be specially useful, given that a strong coupling regime between the electronic mode and the oscillator mode can be generated using only the external field. The possible dynamical regimes obtained in the system are characterized using population dynamics and photoluminescence, as well as studying the crossing and anti-crossing relations. The second one is the possibility of entanglement generation between the internal ion mode and the oscillator mode using a slow-varying external field. The entanglement is measured using the Concurrence. An schematic view of the setup can be observed in the Figure.

FIG. 1. Schematic model of experiment, showing a trapped ion coupled to a nanomechanical oscillator.

METAMATERIAL PATCH ANTENNA BY RECTANGULAR SLOTS

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The physical concepts of metamaterials may be applicable to antenna design for practical applications and improve performances of antennas, such as efficiency, reduction of volume and operating bandwidth. These kind of antennas may provide an alternative for applications in which large bandwidth and use of separated antennas are necessary. The rectangular slot on patch antenna affect resonance frequencies and generated dual band, the addition of more slots can be produce phenomena associated to metamaterial. In this work analyzed as the modification of dimension and position of a set of slots on a patch antenna can be produce phenomena associated to metamaterial patch antenna, specifically resonance frequency shift that can be used for reduction of volume.

References


EFFECT OF PERIODIC SPLIT RING RESONATOR STRUCTURES ON MICROSTRIP PATCH ANTENNA DESIGN

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We have studied theoretical and experimentally the effects that generate periodic structures of split ring resonator (SRR) machined on patch antennas fabricated on FR4 substrate. The coupling between the array of SRRs can be quite complex and strongly depends on their geometrical parameters of arrangement. We have found that for small separation distances, very strong coupling, leading to sharp resonances with high quality factors are observed. The practical implications of these results for the fabrication of a left-handed metamaterial are discussed in this work and we have conducted the theoretical analysis using the vector finite element method. We found that changes in the geometric parameters of the periodic structure of metamaterials allow us to optimize the parameters S11 and VSWR our antennas, but simultaneously change the operating frequency of the patch antenna where this structure is machined.

References


DESIGN AND CHARACTERIZATION COMPACT PATCH ANTENNA WITH DOUBLE NEGATIVE LEFT-HANDED METAMATERIALS STRUCTURES

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A novel design methodology for construction of highly miniaturized patch antennas is introduced. Authors analyzed and explored a significant concept of micro-strip patch antenna configured by double negative left handed metamaterial which have dielectric permittivity and magnetic permeability both negative simultaneously, this complex properties of the proposed structure has been extracted by Nicolson-Ross-Weir (NRW) approach. By using this metamaterial in the antenna structure, the dimension of this proposed antenna is reduced significantly compared to a simple microstrip patch antenna. Simulation results for return loss and radiation pattern of both proposed and conventional antenna are shown and compared using HFSS software. Finally antennas are fabricated using RT duroid 6010 laminates and their properties are measured using Vectorial Spectrum Analyser corroborating results obtained in the theoretical analysis.

References


Study of Induced Birefringence in Microstructures Based in Azopolymer by Two-Photon Polymerization

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In this research was conducted a study of the optically induced birefringence in the azopolymer Hema - HDR13. Generating anisotropy in the material through the photoisomerization process for azo-compounds, the chromophores are reoriented in the material through an external electric field, from an Nd: YAG laser, emitting with a wavelength of 532nm. Based on an absorption spectrum of azopolymer samples was determined that the wavelength at which the phenomenon begins. Measurements were made to determine the degree of birefringence and thus determine which of them can be used as material to design optical storage devices. Also was analysed the theoretical models of photo - molecular orientation, and succeeded in identifying which of them corresponds to the results and establishing the characteristic times appearing in each for Hema - DR13.

References

Exciton-related intersubband optical transitions in asymmetric double quantum wells

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The effects of Aluminum concentration and applied electric field on the exciton states in a GaAs/AlGaAs asymmetric double quantum wells (ACDQW) are studied with both the effective mass and parabolic band approximations. The non-correlated wave function has been obtained via an expansion in terms of sine functions associated with the infinite barrier ACDQW system [1]. The electronic states energies and binding energies of exciton states are calculated as a function of Aluminum concentration, the geometrical confinement and electric fields strength. We discuss the probability of density for the electron and heavy-hole states in ACDQW as a function of Aluminum concentration. Linear and non-linear optical absorption related to intersubband exciton transitions is also studied under the density-matrix formalism [3] as a function of the Aluminum concentration, the applied electric field, and the confinement strength. The results show that the Aluminum concentration and the applied electric field are useful tools to tune the direct and indirect exciton transitions in such heterostructures. Additionally, we present a study the dependence with the width of the confining potential central barrier of double quantum well on the electronic and exciton states and linear and non-linear optical coefficients.

References
Two-dimensional polaritons under the influence of a strong perpendicular magnetic and electric fields

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The properties of the two-dimensional (2D) cavity polaritons subjected to the action of a strong perpendicular magnetic and electric fields, giving rise to the Landau quantization (LQ) of the 2D electrons and holes accompanied by the Rashba spin-orbit coupling (RSOC) and by the Zeeman splitting (ZS) were investigated. The strong magnetic field, when the electron and the hole cyclotron frequencies are greater than the binding energy of the 2D Wannier-Mott excitons completely reconstructs it, transforming into the magnetoexciton, the structure of which is determined by the Lorenz force rather than by the Coulomb electron-hole (e-h) interaction.

We predict the drastically changes of the optical properties of the cavity polaritons including those in the state of Bose-Einstein condensation. The main of them is the existence of a multitude of the polariton energy levels nearly situated on the energy scale, their origin being related with the LQ of the electrons and holes. Most of these levels have the nonmonotonous dependences on the magnetic field strength B with overlapping and intersections. More so, the selection rules of the band-to-band optical quantum transitions as well as of the quantum transitions from the ground state of the crystal to the magnetoexciton states depend essentially on the numbers n_e and n_h of the LQ levels of the e-h- pair forming the magnetoexciton. Changing slowly the external magnetic and electric fields it is possibly to change the lowest polariton energy level, its oscillator strength, the probability of the quantum transition and the Rabi frequency of the polariton dispersion law. They depend on the relation between the numbers n_e and n_h, and can lead to dipole-active, quadrupole-active or forbidden optical transitions. Our results are based on the exact solutions for the eigenfunctions and for the eigenvalues of the Pauli-type Hamiltonian with third order chirality terms and nonparabolic dispersion law for heavy-holes and with first order chirality terms for electrons. They were obtained using the method proposed by Rashba.

We expect that these results will determine also the collective behavior of the cavity polaritons, for example, in the GaAs-type quantum wells embedded into the microcavity, which recently revealed the phenomenon of the Bose-Einstein condensation in the state of the thermodynamic quasi-equilibrium but in the absence of a strong perpendicular magnetic field.
Optical and structural properties of hybrids based on inorganic AlGaN/GaN quantum wells and colloidal ZnO nanocrystals

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Novel hybrid light emitting diodes (LEDs) designed to utilize non-radiative ( Förster) resonant energy transfer ( NRET) from excitation generated in inorganic III-N quantum wells (QW) to excitons in organic films or colloidal nanostructures might have a better efficiency compared to common hybrid LEDs [1]. We have fabricated and studied such hybrid structures based on ZnO nanocrystals (NCs) deposited on the top of AlGaN/GaN QWs grown by metal-organic vapor phase epitaxy as schematically shown in Fig. 1(a). ZnO with the band gap of 3.3 eV plays a role of energy acceptor material while GaN with $E_g=3.4$ eV serves as an energy donor. The AlGaN barrier thickness was adjusted to 3 nm allowing dipole-dipole interaction in the sample. Similar structures, however with thicker barrier layers of 6 and 9 nm, have been grown for control.

Fig.1. (a) Schematic drawing of the hybrid structure, (b) NRET efficiency as a function of temperature for the structure with the AlGaN barrier thickness of 3 nm.

Dynamic properties of QW excitons have been studied by temperature dependent time-resolved photoluminescence (TRPL). The rate of energy transfer can be estimated from the comparison of the QW exciton recombination time with and without acceptor material, i.e. ZnO NCs. We have found a best NRET efficiency at 60 K as shown in Fig. 1(b), while no NRET effect can be observed in hybrids fabricated using control samples with thicker spacer layers.

We also discuss other factors affecting the exciton lifetime in QW, for example variation of the surface potential at the interface between ZnO and AlGaN, degradation of the interface quality due to thermal treatment or as a result of ambient influence.

About possible THz modulator on the base of delta-doped QWs

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It was shown by Bastard [1] more than 30 years ago that in the case of doping quantum well (QW), the (shallow) impurity binding energy greatly depends on the position of the impurity in the quantum well. It is maximal in the QW center and minimal at the QW edge. And it was generally considered that it does not depend on the level of impurity ionization. However, we have shown [2] that it is not so in the case of impurity delta-doping in the QW for not very high concentration of impurities, when it is still possible to treat them as isolated ones. The point is that the Hartree potential arising from the ionization of impurities in the delta layer and free electrons in the QW, superimposed on the original QW energy profile and consequently changed it. In other words, we get a new QW with a new set of the space-quantized energy levels and accordingly with the new ionization energy of impurities. Here we take our attention on the change of energy separation between energy levels. And what is important that it can be executed by a controllable way – by altering the level of ionization of impurities in the delta-layer. It can be done either by changing the temperature or by using a considerably small (shallow impurity!) external electric field. In this work we track the change of energy separation between space-quantized energy levels in a delta-doped Si0.8Ge0.2/Si/Si0.8Ge0.2 QW with the temperature. It is shown that the most dramatic changes are in the case of edge-doped QWs for a few first energy levels, which usually play the predominant role in the light absorption. As the gap between first and second energy levels for a 20 nm wide QW belongs to the THz range, we carry inference of possible using such phenomenon for creation of a THz modulator controlled by a weak electric field. Calculations of absorption for different levels of impurity ionization confirm our suggestion.

References
Dependence of impurity binding energy in a delta-doped quantum well on temperature, quantum well- and delta layer widths


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It was shown by Bastard [1] more then 30 years ago that impurity binding energy depends on the impurity atom position within the quantum well (QW). The picture is changed for the case of (partly) ionized impurity delta layer in the QW. The changes were considered in our works [2, 3]. It was demonstrated that Hartree potential created by ionized atoms in the delta layer and by free electrons in the QW added to the initial QW energy profile. As a result one has a new QW with a new set of space quantized energy levels and accordingly, with a new impurity binding energy (IBM).

In this work we present our new results in this direction. As an object for our investigations, we use Si0.8Ge0.2/Si/Si0.8Ge0.2 QW with different (5, 10, and 20 nm) widths. Different widths of the delta-layers (1, 2, and 3 nm) with uniform and Gaussian distributions of impurities and placed either in the centre or at the edge of the QW were used in our calculations. IBE was found from self-consistent solution of Schrödinger, Poison and electroneutrality equations for different (4, 77, and 300 K) temperatures.

It is shown that ionization of the delta layer leads to the increase of IBE, which is the most pronounced for edge-doped QWs with the biggest (and allowed for treating impurities as isolated ones) impurity concentration. We consider as important findings the facts that: (1) IBE for edge- and centre-doped QWs have a trend to approach to each other with the level of impurity ionisation and that (2) increasing impurity concentrations involves an increase of IBE. It is demonstrated that the difference between results obtained for the uniform and Gaussian impurity distributions across the width of the delta layer is so small that allows using uniform distribution instead of a Gaussian distribution of impurities. The dependences of IBE on the QW width and width of the delta layer, and impurity concentration are also analyzed.

References
Intraband optical response of the delta-doped SiGe quantum wells

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Intersubband transition in semiconductor quantum-confined structures are the perspective basis for the engineering new kinds of optical devices covering terahertz range of spectrum. One of the possible configuration to work with are stressed Si/GeSi quantum well structures, n-delta-doped inside the well. The shallow impurity of delta-layer in such a structures can easily be ionized with external parameters like temperature and/or electric field, distorting the well energy profile with a superposition of Hartree potential of electrons in quantum-confined subbands and the potential of ionized delta-layer, thus efficiently changing the electronic structure (including transition energies) of the system. Consequently, the effect can be used to tune easily the presumable devices using quantum-well-delta-doping configuration.

In our work [1] we developed the self-consistent technique to calculate electronic structure of such a configuration allowing for the Hartree potential distortion of energy profile and taking into account the change of impurity binding energy, which is calculated within the approach described in [2]. In this work using that technique we calculate and analyze the linear and nonlinear optical response, including absorption coefficient and refractive index of 20 nm-wide Si\textsubscript{0.8}Ge\textsubscript{0.2}/Si/Si\textsubscript{0.8}Ge\textsubscript{0.2} QW structures delta-doped either in the center or in the edge of the well under the different temperatures. Our calculations show that the degree of ionization of impurity layer as well as the symmetry has a strong influence on both linear and nonlinear parts of calculated values.

References

Intense laser field effects on a Woods-Saxon potential quantum well

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Several authors have shown that the Woods–Saxon (WS) potential can be used to model the confinement in quantum wells with considerable success [1-3]. This paper presents the results of the theoretical study of the effects of non-resonant intense laser field and electric and magnetic fields on the optical properties (the linear and third-order nonlinear) in an quantum well with WS potential profile. The electric field and intense laser field are applied along the growth direction of the WS quantum well and the magnetic field is oriented perpendicularly. To calculate the energy and the wave functions of the electron in the WS quantum well, the effective mass approximation and the method of envelope wave function are used. The confinement in the WS quantum well is changed drastically by the application of intense laser field or either the effect of electric and magnetic fields. We follow the model of Lima et al. [4] that predicts the formation of a double-well potential for laser intensities such as the dressed laser parameter is larger or equal to the half of quantum well length, which creates the possibility of generating resonant states into the WS quantum well. The optical properties are calculated using the compact density matrix approach. Our results show the presence of shifts to higher photon energies by the effects of electric and magnetic fields and shifts to lower photon energies due to changes in the quantum profile from single to double quantum well potential induced by intense laser fields. In general, it is found that the electric and magnetic fields and intense laser field are external agents that modify the optical responses in the WS quantum well.

References

Aharonov-Bohm oscillation modes in non-uniform quasi-one-dimensional ring under lateral electric field

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Low-lying states of a narrow one-electron nanoring with variable thickness in the presence of threading magnetic and lateral electric fields are analysed by using the adiabatic approximation [1-2]. In this technique the problem is reduced to a one-dimensional Schrödinger equation that describes the rotation of the electron along the ring in an axially non-homogeneous effective field whose potential depends on both the variation of the nanoring thickness and the external electric and magnetic fields. We solve this equation by using the Fourier method and present novel curves for energies of lower levels and the magnetization as functions of the magnetic and electric fields for structures with different profiles given by periodical dependencies of the ring thickness on the azimuthal angle. We show that the electronic properties of narrow nano-rings are very sensitive to both the external electric field and the structural non-homogeneity. Particularly, the non-homogeneous height of the ring and the in-plane electric field provide each one the electron localization and a quenching of the Aharonov Bohm oscillations for lower states, but if they act together the oscillations reinforcement instead of their quenching can be achieved. This opens a new possibility to control nanoring properties by external electric field.

References

Self-similar Transmittance in Graphene-Based Aperiodic Cantor Potentials

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We investigate the transmission properties through quasiperiodic or aperiodic structures based on graphene arranged according to the Cantor sequence. In particular, we have found self-similar characteristics in the transmission spectra, so the scalability of them is studied. Specifically, we implement and propose scaling rules for each one of the fundamental parameters (generation number, height of the barriers and length of the system) finding an excellent agreement between the scaled curves and the reference ones (Fig. 1). Finally, it is worth mentioning that the peculiar geometrical characteristics of the fractal sequence are manifested in the physical properties such as the transmittance.

Figure 1: Scaling between generations: the generation numbers selected are N=5 and N=6 corresponding to the solid-black and solid-blue lines, respectively. The dotted-red lines represent the generation N=6, which now is the scaled curve. The starting width and the height of the barriers are $w = 540a$ and $E_0 = 0.13$ eV.
Photoinduced mid-infrared light absorption and photoconductivity in Ge/Si quantum dots

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Optical studies of Ge/Si quantum dots (QD) in mid-infrared spectral range are of particular interest because of the possibility to develop detectors of infrared radiation. Also, some properties of dots and Ge/Si interface are not still clearly understood. In this paper we present the results of the studies of light absorption and photoconductivity related to intraband and interband optical carrier transitions in undoped and slightly doped Ge/Si quantum dots when nonequilibrium carriers are created with interband optical pumping. Photoexcitation makes possible to use QD excited states as initial ones in optical transitions and gain additional information.

Structure under investigations contained 10 periods of Ge/Si quantum dot layers grown on Si substrate using MBE. Structures with low doping level and non-intentionally doped structures were used. Samples for investigations were prepared in multipass geometry, providing the possibility to measure spectra of photoconductivity and absorption for p- and s-polarized light. Radiation of solid-state 532 nm laser was used for interband optical excitation.

Photoinduced absorption was detected in 0.25-0.6 eV spectral range. Absorption modulation spectrum contains both positive and negative parts. In conditions of optical excitation the absorption of z-polarized light increases in low-energy side of the spectrum related to optical intraband hole transitions. This is explained with additional nonequilibrium holes generated in QD. Absorption of z-polarized light in high-energy side of spectrum decreases under optical pumping. Absorption in this spectral range is connected with interband carrier transitions between ground hole subband in QD and electron levels arising in Si matrix due to band bending [1, 2]. In conditions of interband optical pumping, the dynamic analogue of bulk Burstein-Moss effect can be observed: interband optical absorption is impossible in case the final states for charge carriers are filled with carriers generated by pump radiation. Polarization dependency of the interband absorption can be related to the complicated potential profile of the silicon conduction band at the quantum dot heterointerface [2].

Photoinduced photoconductivity spectra were also measured in low-doped structures in the spectral range corresponding to hole transitions from low QD energy states to continuum of the states above the well. Spectra of photoconductivity without interband excitation were measured earlier [3]. The value of photoconductivity and the shape of its spectrum change under interband excitation. We attribute these phenomena with additional population of the ground and first excited hole states by nonequilibrium holes. Spectrum of the photoconductivity agrees well with the absorption spectrum.

References

Excitation energy transfer in hybrid nano-systems by a multi-scale Förster approach

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We developed a new multi-scale approach to treat excitation energy transfer in hybrid nano-systems composed of a chromophore attached to a semiconductor nanoparticle (NP), a class of nano-materials of growing relevance in diverse fields, from artificial photosynthesis [1] to nanomedicine. Since such systems may be composed of millions of atoms, their optical excitations are often described by ab-initio methods selecting a small active optical center, comprising the chromophore and a cluster of tens/hundreds of semiconductor atoms [2]. However, this may not be appropriate in many situations, e.g., when the optical excitations of the chromophore are resonant with those of the NP, which is extended over the entire nano-system.

In our method, optical excitations of each subsystem is accurately described within a quantum-mechanical approach at the appropriate level of description, that is a state-of-the-art ab-initio description for the chromophore and an accurate, yet semi-empirical envelope-function description of excited electron-hole pairs (excitons) for the NP. Energy transfer between excitations in different segments are described here by a Förster approach [3] whereby the dipole coupling terms are calculated using the fully correlated states of the separate segments. This method allows for an accurate description of the dynamical correlations inside each segment, including multi-exciton generation in the NP, dielectric screening of the chromophore from the solvent and the nanoparticle polarization, and dielectric screening of the electron-hole pair interaction. Furthermore, it includes the interaction between excitations within an approximation which is accurate for not too short chromophore-nanoparticle distances.

This novel approach is applied to case studies relevant for artificial photosynthesis, where the chromophore is a biological optical active molecules such as conjugated systems and porphyrines, and the nanoparticle is made by a III-V semiconductor such as GaAs.

References

Nonlinear optical response in GaN cylindrical quantum dot: Effects of external electric and magnetic field

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We calculate the nonlinear optical susceptibility of a GaN cylindrical quantum dot including the effects of external electric and magnetic fields. The electron eigenstates are obtained using an effective mass approximation scheme with parabolic confinement and external fields. The nonlinear optical susceptibility is found through the solution of the density-matrix Bloch equation. We present a study of the dependence of the eigen-energies respect the electric and magnetic field intensity. Our main findings show that the resonant peaks of the nonlinear optical properties can be red or blueshifted by using the different parameters involved in the problem (cyclotron frequency of the confinement potential and electric and magnetic field intensities).

References

Transport and thermodynamic properties of Biphenyl molecules

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In the present work we study the electronic as well as thermodynamic properties of a single Biphenyl molecule coupled to two contacts. We study these molecules based on the tight-binding approach. [1]. The calculations of the transport properties calculation are performed using non-equilibrium Green’s functions techniques inside of a discrete space. In particular, we use a decimation procedure [2, 3]. The transmission probability, current, conductance and thermo-electrical power are obtained following the Landauer-Büttiker formalism [4, 5, 6, 7]. The results show that the Biphenyl molecule may be have semi-conductor behavior for certain values of the junctions electrode-molecule-electrode. In addition, we have calculated the density of states (DOS) is calculated to compare the width of the bands with the profile of the transmission probability. DOS helps us to explain the an asymmetric shape respect to Fermi energy of the molecule.

References

Preparation of Fe$_3$O$_4$/TiO$_2$ nanoparticles for photocatalysis of aqueous contaminants

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The use of magnetic and oxide nanoparticles has increased in recent years for environmental applications, such as in the photocatalysis of organic pollutants in aqueous systems [1, 2]. For this application, we have synthesized magnetite (Fe$_3$O$_4$) nanoparticles from the co-precipitation method obtaining small aggregates with a hydrodynamic size of 46 nm, which displayed a saturation magnetization of 48 emu/g. Titanium dioxide (TiO$_2$) nanoparticles were obtained from an eco-friendly process by the precipitation of titanium isopropoxide solution using lemon grass leaves extract. From X-ray diffraction, we observed that the synthesized TiO$_2$ nanoparticles exhibited a crystal size of 19 ± 4 nm and a 96% of the crystal phase anatase. Magnetic/photocatalyst nanocomposites were prepared by the encapsulation of Fe$_3$O$_4$ nanoparticles in a poly-siloxane matrix, which allowed the graft of titanium dioxide (TiO$_2$) nanoparticles at room temperature. From this methodology, we obtained two samples of nanocomposites, labeled as samples A and B, after the addition of 0.1 g and 0.3 g of TiO$_2$ nanoparticles, respectively. The photocatalysis capacities of the synthesized nanocomposites were tested in aqueous suspension at pH 3.0 using a phenol solution prepared at 50 ppm. The synthesized nanocomposites were added at concentrations ranged from 0.2, 0.5, and 1.0 g/L. Photocatalysis process was carried out by using ultraviolet irradiation UV (λ=375 nm) during 6 h with a constant agitation of 100 rpm. Afterwards, it was observed a photocatalysis of up to a 95% of phenol by using the nanocomposite-B with a concentration of 0.2 g/L. After the nano-photocatalyst process, the multifunctional nanoparticles were removed from the aqueous media by applying a magnetic field. We also evaluated the possibility to re-use these nano-materials observing a 25% decrease of their photocatalytic activity after 5 continuous cycles of photocatalysis, suggesting the versatility of the synthesized Fe$_3$O$_4$/TiO$_2$ nanocomposites for the photocatalysis of organic pollutants.

![Figure 1: Photocatalysis of phenol by using nanoparticles and UV-irradiation during 6h.](image)

References
Modification of a cellulose triacetate membrane with silver nanoparticles for forward osmosis water treatment

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Forward osmosis has gained considerable attention in many potential applications, such as power generation, desalination, food processing and wastewater treatment, thus showing an increase in research for the optimization of this process [1]. As a membrane technology, the increase of the membrane’s performance and diminish of fouling is of crucial importance. Silver nanoparticles have emerged as an optimum nanomaterial for the inhibition of bacterial growth [2]. In the following paper, a novel method for the modification of a cellulose triacetate membrane with silver nanoparticles is described. Triethanolamine was used as a reducing agent in concentration of 0.1 and 1 M, which facilitated the in situ formation of the nanoparticles on the commercial membrane. Subsequently, the modified membrane was implemented in a lab scale direct osmosis system for the treatment of water from the Las Quintas swamp in the city of Cartagena, Colombia. The membrane was characterized with UV-Vis spectroscopy, that determined a range of absorption between 440 and 450 nm that corresponds to the superficial plasmon resonance of the membrane particles. Also, FTIR analysis was performed to determine the presence of silver nanoparticles in the membrane, giving a peak at 1385 cm⁻¹, which corresponds to silver. Thermograms were obtained for DSC and TGA, which yielded the melting and crystallization temperatures and major weight loss. The effectiveness of the nanoparticles as an antimicrobial agent was determined by contacting them with E.coli during periods of 24 and 48 hours, zones of inhibition were observed up 15 mm. Finally, the effectiveness of the membrane in the forward osmosis system was evaluated, obtaining removal percentages of total coliform and E.coli of 98.8% and 98.6% respectively, in addition, a treated water flux of 0.06 L/m²h, corroborating, the efficiency of forward osmosis as a viable alternative for wastewater treatment.

Figure 1: SEM Images of a cellulose triacetate membrane modified with silver nanoparticles.

References
Synthesis of magnetic nanoparticles coated with covalently bonded carboxymethyl cellulose

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Magnetite nanoparticles were synthesized by the co-precipitation method and then they were functionalized with the aminopropyl silane (APS) molecule to provide amine groups onto the nanoparticle surface [1]. These amine groups were used to covalent bond the hydrophilic polymer carboxymethyl cellulose (CMC) around the nanoparticles by using carbodiimide chemistry [1]. The crystal size of the magnetite nanoparticles was determined by using X-ray diffraction (XRD) technique, from which it was determined a crystal size of approximately 30 nm. After modification with the CMC, the nanoparticles exhibited a hydrodynamic size of about 172 nm, according to the dynamic light scattering (DLS) analysis. Additionally, we used the infrared spectroscopic technique (FTIR) and the thermogravimetric analysis (TGA) to determine the graft of CMC molecules onto the magnetic nanoparticles. From these analyses we estimated a 15% of organic composition, suggesting the complexation of the CMC molecules on the nanoparticle surface, as the CMC has ~388 carboxyl groups per chain. A scanning electron microscope (SEM) was used to get images of the magnetite-CMC nanoparticles, from which it was observed the formation of clusters like agglomerates, indicating the possible aggregation of these nanomaterials during the modification process, which yielded a highly hydrophilic magnetic nanomaterial.

Figure 1: TGA analysis of magnetic-CMC nanoparticles.

References
Green Synthesis of Silver Nanoparticles for Antimicrobial Applications

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We studied the green synthesis of silver nanoparticles from a silver nitrate solution prepared at concentrations of 1.0 and 100 mM. Moreover, we used a natural leaf extract from guava plant, which allowed the formation of nanoparticles without the production of traces of toxic pollutants. The physical-chemical properties of the synthesized nanoparticles were determined by using spectroscopic techniques such as UV-Vis, from which we observed absorption at the wavelength ranging from 430 to 455 nm\(^{-1}\), which is characteristic of the surface plasmon resonance of the silver nanoparticles. Additionally, we used the dynamic light scattering to determine the hydrodynamic size of the synthesized nanoparticles, obtaining an average size of 75 ± 30 nm. To determine the susceptibility of these nanoparticles to be used as antimicrobial agents in the production of bio-active food packages, the synthesized silver nanoparticles were dispersed in samples of paper pulp, which are mainly formed by cellulose and can be used as a hydrophilic support of the nanoparticles. The cellulosic materials modified with the nanoparticles were put in contact with the \textit{E. coli} bacteria during 24 and 48 h, from which we observed the inhibition of the bacteria growth by following the standard procedure described for Bauer-Kirby (1966), which indicated the potential opportunity for the application of these nanomaterials as antimicrobial agents.

Figure 1: UV-Vis spectroscopy of silver nanoparticles synthesized from an aqueous AgNO\(_3\) solution prepared at a) 1mM and b) 100 mM.

References

X-ray magnetic circular dichroism on LCMFO thin films

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The element-selective X-ray magnetic circular dichroism (XMCD) technique [1] has been used to study the magnetic properties of La2/3Ca1/3Mn0.97Fe0.03O3 (LCMFO) thin films. Samples have been grown by dc magnetron sputtering on (100)-SrTiO3 (STO) and (100)-LaAlO3 (LAO) single-crystal substrates. XMCD measurements below the ferromagnetic ordering temperature under an external magnetic field of ±1 T at the Mn and Fe L2,3 absorption edges allow determination of the contributions and relative orientations of the Mn and Fe magnetic moments. A reduction in the Mn L2,3 XMCD signal of the LCMFO sample compared to that for the parent La2/3Ca1/3MnO3 (LCMO) system reveals important modifications in the electronic and magnetic properties with the presence of Fe. The Fe L2,3 X-ray absorption (XAS) for the LCMFO film is characteristic for Fe3+, and comparison with multiplet calculations [1] suggests that the Fe dopants occupy octahedral sites in the crystal, which is consistent with Fe3+ substituting Mn3+ in LCMO. The magnetic moments of Mn and Fe are found to align antiferromagnetically, which suggests the presence of Mn-O-Fe superexchange coupling. This result is consistent with macroscopic magnetometry measurements on the LCMFO system, which show a decrease in saturation magnetization of LCMO with Fe doping [2].

![Figure 1: XAS and XMCD at the Mn L2,3 edges for LCMO and LCMFO films grown on (a) STO and (b) LAO substrates. Dashed lines correspond to the integral of the XMCD signal for each sample. (c) XAS and XMCD at the Fe L2,3 edges for the LCMFO film grown on STO. The calculated XAS and XMCD for Fe3+ d5 in octahedral site symmetry are shown for comparison.](image)

References
Absorption Coefficient for a double \( \delta \)-doped GaAs MIGFET-like structure: electric and magnetic field effects

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In this work we presented the results for the electronic structure computation as well as the absorption coefficient for a double \( \delta \)-doped like multiple independent gate field effect transistor (MIGFET) potential profile. We are modelling the potential as that will correspond to a double \( \delta \)-doped quantum well between two Schottky barrier potentials. In this kind of quantum structures it is important to investigate the effect of external fields on the electronic and optical properties. In this work we are reporting the absorption coefficient for this potential profile as a function of electric and magnetic field effects. We consider the effect of an homogeneous electric field in the growth direction (\( z \)) and the magnetic field applied in \( x \), as depicted in figure 1. By working in the effective mass approximation, we found that: 1) the main transition energy slightly decreases as a function of an increasing positive electric field leading to an augmented redshift of the absorption coefficient, and 2) as the magnetic field is increasing the resonant peak of the absorption coefficient experiences a blueshift as well as an important increase in its magnitude.

![Graph](image)

Figure 1: Potential profile for the double \( \delta \)-doped like MIGFET potential profile.
Comparative Study of the Raman Modes in Pure and Fe-doped 
\( \text{La}_{2/3}\text{Ca}_{1/3}\text{MnO}_3 \) Thin Films

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We report a comparative study of Raman modes at room temperature on \( \text{La}_{2/3}\text{Ca}_{1/3}\text{MnO}_3 \) (LCMO) and \( \text{La}_{2/3}\text{Ca}_{1/3}\text{Mn}_{0.97}\text{Fe}_{0.03}\text{O}_3 \) (LCMFO) thin films grown on \( \text{LaAlO}_3 \) (LAO) substrate. The films were prepared by using magnetron DC-sputtering technique for different thicknesses between 30 and 160 nm. Raman spectra were taken in a spectral range between 200 cm\(^{-1}\) and 800 cm\(^{-1}\), using the 632.8 nm line of a He-Ne laser. X-ray diffraction and Raman spectroscopy analysis reveals the effect of thickness on the lattice parameters and Raman modes in these films. In order to observe changes in the vibration modes of the lattice due to the substitution of Mn by Fe ions in LCMFO films, the different values of wave numbers obtained from the fits of each spectrum were compared. The exact positions and line widths of various Raman modes were obtained by using the Lorentzian fit (figure 1a). The results show that the characteristic peak due to their intensity corresponds to the substrate ~ 486 cm\(^{-1}\). In the undoped LCMO thick films, Raman modes are very weak and confused with the substrate, whereas in LCMFO doped films, it were found in three intervals around 220-250 cm\(^{-1}\) (\(\nu_1\)), 450-520 cm\(^{-1}\) (\(\nu_2\)) and 610-720 cm\(^{-1}\) (\(\nu_3\)). \(\nu_1\) modes are associated with rotational modes of (Mn / Fe)O\(_6\) octahedra and \(\nu_2\) and \(\nu_3\) modes are assigned to Jahn-Teller effect. Additional, we carry out measurements of the resistivity as a function of temperature, and analyzed the results in the framework of some transport models such as small polaron hopping and Mott’s variable range hopping (VRH). The results from the fitting of the experimental data allowed evidencing the Fe effect in the transport properties and in the vibrational modes in both systems (figure 1b). These will be discussed in detail.

![Figure 1:](image)

Figure 1: (a) Raman spectra of LCMO and LCMFO thin films. The oval shows the vibration mode in 717 cm\(^{-1}\) in LCMO film. The dotted lines indicate the bands around 440 cm\(^{-1}\) and 600 cm\(^{-1}\). The central sharp peak corresponds to the characteristic mode of the LAO substrate. (b) Temperature dependence of the resistivity in zero field between 5 to 300K of the LCMO and LCMFO films. All films reveal a metal-insulator transition temperature which is shifted lower temperature with Fe doping.
Metamaterial-polaritonic photonic superlattices

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We have performed a theoretical study of the light propagation in photonic superlattices composed by alternating slabs of polaritonic and negative refractive media. Numerical results were obtained by using the well known transfer matrix method (TMM). Present results indicate the possibility to simultaneously have both, the zero-\(\tilde{n}\) and the zero-\(\phi_{\text{eff}}\) gaps in this kind of photonic systems. In addition, we have observed that the zero-\(\tilde{n}\) non-Bragg gaps remains almost invariant with the incident angle for both, TE and TM, polarizations, while the zero-\(\phi_{\text{eff}}\) gap only remains omnidirectional for TE polarization if single negative electric (SNE) like-polaritonic, and for TM polarization in the case of single negative magnetic (SNM) polaritonic-like metamaterials.

We are grateful with the Colombian agencies COLCIENCIAS and CENM-UNIVALLE. J.R. M-S is supported by a Post Doctoral Fellowship grant of the Programa Nacional de Pós-Doutoramento (PNPD/CAPES) at the Universidade Federal de Alagoas (UFAL) through the Project Nr. 02727/09-9.
Quantum Limit for Driven Linear Non-Markovian Open-Quantum-Systems

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In this work we considered the interplay between driving fields and Non-Markovian dynamics in the generation of squeezing and survival of entanglement between two nanoresonators in the high-temperature regime. Based on exact analytical results for the Non-Markovian dynamics of two parametrically coupled nanoresonators in contact to independent thermal baths, the out-equilibrium quantum limit derived in \cite{1} is generalized to the Non-Markovian regime. It is shown that the Non-Markovian dynamics, when compared to the Markovian case, allow for the generation of squeezing and the survival of stationary entanglement in the long-time regime at higher temperatures, with larger coupling strengths to the baths and at smaller driving rates. We also considered the effect of asymmetry of the coupled resonators, coupling strength to the baths at equal temperature and temperature at equal coupling strength.

References

Fast Monte Carlo study of the magnetic properties of Fe/Ni core/shell cylindrical nanostructures

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In this work we use the Fast Monte Carlo Method, which consists in the combined application of the Scaling Technique with Monte Carlo simulations, to study the magnetic states and the inversion mechanisms of magnetization in nanometric core/shell cylindrical system composed by Fe(tec)/Ni(fec). The interest in this kind of structures involving core/shell morphology resides in the novel properties, not obtained through the individual components, which can be potentially employed in sensors, catalysis, drug delivering and information storage, among others. The sizes of the samples of this study are 20 nm for the height of the nanostructures, 65 nm in diameter for the Fe core; and the external diameters for the Ni shell are in the range 70-125 nm. The study involves the computation of exchange and dipolar energies as well as the Zeeman interaction of the samples with an external magnetic field.

Figure 1: Hysteresis loops for two selected samples with 90 and 95 nm as external diameters. Different kinds of magnetic reversals are observed as function of size. Some snapshots are included to show magnetic configurations at different applied magnetic fields.

Results indicate that the minimum energy magnetic configuration corresponds to a vortex state for the combined core/shell systems as well as for the individual parts (core and shell). However, all the systems exhibit another meta-stable magnetic configurations depending on the interaction between inner and outer subsystems and the size of them. These results are related with the change of the localization of the valence electrons occurring whenever the size of the samples is varied; along with the shape effects, the structural modifications and the different interactions among atoms located on the interface of the components of the systems. The hysteresis analysis shows a clear effect of size on the magnetization rotation mechanism. For external diameters below 110 nm inversion takes place through bar-magnet-like state while for bigger diameters a coherent rotation is inferred. Results indicate that these structures could be employed for technological applications in the fields of magnetic sensing.

This study has been supported by: FONDECYT grant Nº 1130672; Conicyt PIA ACT1108, Postdoctorado 3150525; IN3068CE UdeA project; "Financiamiento basal para centros científicos y tecnológicos de excelencia FB 0807", and CONICYT-COLCIENCIAS 2015-2016.
Rabi oscillations of photon-dressed electrons in graphene

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The interaction of circularly polarized $ac$ fields with Dirac electrons in a graphene monolayer has been studied. We have found that the population inversion of photon-dressed electrons describes Rabi oscillations in a similar way as do it atoms with two levels. Furthermore, in the f-oscillator formalism, to quantify nonlinear optical effects, deformation operators were introduced. The effect of population inversion of photon-dressed electrons in graphene, presented in this work, promotes this system as a good active optical medium for the design of photonic and optoelectronic devices.
Optical quantum oscillations of the density of states of photon-dressed electrons in a graphene layer

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In this work, the density of states for a graphene monolayer in presence of circularly polarized ac fields is studied. We show that, the shifting, driven by the field frequency, of a periodic structure of photon-dressed electron states, within an energy gap, leads to a periodic change of electron singularities in the density of states and consequently in thermodynamic and transport properties of the graphene monolayer.
Synthesis and characterization of silver nanoparticles using *Canna indica* L. starch as reducing agent

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In this work synthesis of the Ag silver nanoparticles (AgNPs) were performed using *Canna indica* L. starch as a reduct agent, according to Ayala et al (1). Different concentrations of starch solution (0.5, 1.0, 1.5 and 2.0 W/V) were prepared. The synthesis process was performed at 90°C during 1, 6 and 12 h, in order to analyze the growth kinetic; after that, the samples were characterized using UV-visible spectroscopy, Transmission Electron Microscopy (TEM). The software Image J was used to obtain the average diameter. Antimicrobial active of the silver nanoparticles was performed with *Listeria monocytogenes*. UV-visible verified the reduction of silver ions, showing the characteristic surface plasmon resonance of conduction electrons (SPR), which goes from the surface of the silver nanoparticles (2). The maximum and minimum absorbance, by UV-visible, were 2.7185 at 406 nm (sample of 2 W/V at 12 h), and 0.5742 at 410 nm (sample of 0.5 W/V at 1 h), respectively. The average diameter of spherical AgNPs decreased with increasing in the starch concentration and the time in the thermal bath; for 0.5 W/V and 1 h, it was 21 nm. In contrast, at 2 W/V and 1 h, the average diameter was 6nm. The highest antimicrobial activity was found at 2% during 12 h, with an inhibition halo of 15 mm. In conclusion, the synthesis of silver nanoparticles was successful and their antimicrobial activity in *Listeria monocytogenes* was better at higher concentration of starch and exposure to thermal bath.

References


Effects of intense laser and hydrostatic pressure on the ground molecular state of a single ionized two-hydrogenic system in GaAs/Al_xGa_1-xAs quantum well

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Recently, there has been remarkable interest on semiconductor nanostructures in order to boost the development of the quantum computation. In this regard, a single ionized double-donor system D+ confined in low-dimensional systems [1-2] have been proposed to encode logical information. Motivated by these theoretical grounds, we analyze the combined effects of intense laser and hydrostatic pressure on the electronic behavior and salient molecular features of a D+ complex confined in finite GaAs/Al_xGa_1-xAs quantum wells. Solution of Schrodinger equation is obtained by using variational procedure. The D+ binding energy is calculated as a function of the quantum well width for different values of the hydrostatic pressure and the laser-dressing parameter. Besides, by calculating the D+ total energy as a function of donor-donor separation it is possible to analyze the role of hydrostatic pressure and laser-dressing parameter on D+ turning points and its stability. Finally, we show that our results are in good agreement with those previously reported in the limit cases.

References

Excitonic states in vertically stacked quantum dots: combined effects of the structural asymmetry and external magnetic and electric fields

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Vertically stacked quantum dots have awakened a great deal of attention as a possible quantum gates required to entangle different exciton states. In this work, we consider an electron-hole pair spatially separated in non-identical and vertically aligned InAs-GaAs quantum dots in growth-direction applied magnetic and electric fields. In this regard, the upper quantum dot has base radius and height different than lower one. By considering a simplified exactly solvable quasi-two-dimensional model with parabolic lateral confinement, the wave functions and low-lying energy states of the electron-hole system is obtained by using Galerkin method [1]. From this model, the effect of quantum dots structural asymmetry on the electron-hole energy structure has been considered by calculating the density energy states as a function of the ratio between the base radii and the heights of the upper and lower quantum dots. Different inter-dot separation and the electric and magnetic field strengths have been considered in our calculations.

References

Hydrostatic pressure effect on the two-electron energy structure in anisotropic quantum dot: Fractal dimension approach

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In recent years, the interest on the two-electron problem is bound to the studying of their electronic behavior under strong confinement conditions in QDs, due to the triplet to singlet relaxation time ranging between order of 1 μs and 1 ms. This experimental fact favors the development of potential applications in quantum computing [1] and spintronics [2]. In the present work we analyze the effect of hydrostatic pressure, temperature and aluminum concentration on the spectrum of two-electron quantum dot with anisotropic parabolic confinement by using the fractional-dimension approach. From the method implemented in the present work, it is possible to reduce the two-particle problem to two equations for independent particles in an effective space with variable dimension ranging between two and three for ellipsoidal-shaped quantum dots and between one and two for elliptical-shaped quantum disks. The dependencies of energy levels on the heterostructures sizes for quantum dots, disks and wires are presented. Our results are in good agreement with those previously reported for limit cases.

References

Off-axis magneto-donor impurity in a non-uniform height quantum ribbon

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In recent years, semiconductor nanotubes with very thin wall have been formed by using a new technology [1-2]. These semiconductor nanostructures may find applications in nano-electronics and dynamic quantum mechanics because they offer several advantages in comparison with other low-dimensional systems. Motivated by this finding and taking into account that these nano-ribbons are not uniform, we propose to analyze the energy structure for a single and off-axis donor under axial external magnetic field. By considering nanoribbons with very small height-to-radius aspect ratio and considering periodic functions to define the non-uniform height, it is possible to use the adiabatic approximation in order to separate the fast motion in axial direction from the slow rotation motion. The corresponding angular dependent Schrödinger equation can be solved in the framework of the exact diagonalization method. The results of calculation show that the Aharonov-Bohm oscillation structure is very sensitive to changes in the periodic parameters of the height function: amplitude and the nano-protuberances sizes. Additionally, the oscillation structure can be modified by changing the donor position since the closer is the fixed donor to ribbon the deeper is the localized states and the greater is the number of located energy states.

References

Two-electron Vertically Coupled Nanorings: The simultaneous effects of hydrostatic Pressure, magnetic field and temperature

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Ring-like nanostructures have recently captured a profound interest in theoretical and experimental studies since the few charge carriers energy spectrum in such nanostructures is strongly dependent upon the ring morphology and applied electric, magnetic or hydrostatic pressure fields [1]. Current theoretical works on quantum computing [2] have motivated to consider nanostructures as an ideal scenario to develop this field inasmuch as offer great possibilities to tune the energy spectrum of few-particle systems thorough external probes. In this regard, these important findings aimed this present work where computational calculations of the two-electron energy structure in different-sized vertically stacked nanorings under the presence of hydrostatic pressure and a uniform magnetic field have been performed. Additionally it is analyzed the operation temperature influence in the range of 4 to 200 K. Results shown that the hydrostatic pressure and magnetic field have opposite effects, the former one reduces the energy level values and the magnetic field rises them, being more predominant the last one. The well-know Aharonov-Bohm diamond pattern is slightly altered by the hydrostatic pressure influence, but the ring-ring distance increment yields to a substantial modification of the pattern periodicity. Finally, our numerical results are in excellent agreement with those obtained by exact models as the cross-sections dimensions of the rings are slight.

References
Exciton in non-uniform ring-like nanostructure with double rim

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Abstract

We study the effect of the anisotropy in the rims heights on the spectral properties of the exciton confined in a double concentric InAs/GaAs circular quantum ring in the presence of the external magnetic field applied along the symmetry axis. To this end we consider a model in which the thickness of the structure is increased linearly with different slopes between the axis and inner rim and between the inner and outer rims, respectively. The anisotropy in the heights of rims, originated by the presence in the structure of few valleys, we simulate in our model by introducing periodic dependence of the slope on the radial direction. We show that one-particle wave functions of the electron and the hole confined in isotropic structure can be found analytically, and one can use them as base functions for analyzing the influence of the electron-hole interaction and the anisotropy of heights of rims on the spectral properties of the exciton in the framework of the exact diagonalization method. The dependencies of the exciton energies as functions of the magnetic field, the radii and heights of the rims, as well as of the number of the valleys and their depths is consistently described with our formalism. Our results reveal that a tiny variation of the rims heights produces a drastic alteration of the period and the amplitude of the Aharonov-Bohm oscillations, and it leads besides to a strong entanglement of the states with different radial and orbital quantum numbers.
Theoretical Study of Nitrogen Incorporation Into Au-fcc Structure

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ABSTRACT

The 4d and 5d series of Transition Metallic Nitrides (TMN) is being studied in the last decade, due to the experimental obtaining of AuN, PtN, CuN compounds. In this paper, plane-wave pseudopotential Density Functional Theory (DFT) was used to study the incorporation of nitrogen atoms inside of the golden (Au) fcc lattice. Nitrogen atoms were located at tetrahedral (TH) and octahedral (OH) sites, with the percentage of 30%, 50% and 60%. The AuN stabilized in: 2OH (30%), 4OH and 4TH (50%), 4OH – 2TH (near to wurtzita structure) and 6TH (60%), which indicates that AuN could have a behavior of Transition Metallic Nitride, because to that the nitrogen atoms energetically prefer the tetrahedral sites.

Key Words: Nitrogen Atoms, Au-fcc Structure, Octahedral site, Tetrahedral Site, Gold Nitride.
An \textit{ab-initio} DFT+U study of the electronic and magnetic properties of nickel-doped wurtzite AlN

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Abstract:

We carried out \textit{ab-initio} spin-polarized calculations in order to study the structural, electronic and magnetic properties of the Ni-doped AlN wurtzite semiconductor. Calculations are based on density functional theory (DFT) within GGA and GGA+U formalisms for exchange and correlation potential. Formation energy and electronic structure calculations have been performed for ferromagnetic and antiferromagnetic states of Ni\textsubscript{x}Al\textsubscript{1-x}N (x=0.056) by GGA and GGA+U formalism, respectively. The present calculation reveals that when the Al atom is substituted by the Ni atom in the AlN semiconductor, a Ni-Ni distance-dependent ferromagnetic-antiferromagnetic ground state is observed. A magnetic moment per Ni atom of about 3.00 $\mu$B is predicted for Ni\textsubscript{x}Al\textsubscript{1-x}N (0.056$ \leq x \leq 0.125$). The results indicate that the ferromagnetic ground state originates from the strong hybridization between Ni-d and N-p states, which is in agreement with previous studies on d doping in wide gap semiconductors. Room temperature ferromagnetism in Ni\textsubscript{x}Al\textsubscript{1-x}N (x=0.056) is expected with an energy difference of $E_{FM-AFM}$ (293 meV), which is in good agreement with the experimental observations.

\textbf{Keywords:} AlN, Diluted magnetic semiconductor, Density-functional calculations.
Implementation and automation of a Faraday magnetometer for magnetic characterization of solids and fluids

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Abstract
In this work we present the design, assembly and testing of a Faraday magnetometer developed for the characterization of magneto optic properties of solids and fluids. The magnetometer was automated by using programmable equipment controlled by the port IEEE488 through SCPI commands executed from a graphical interface developed in the LabVIEW software. The Verdet constants of water and a ferrofluid of magnetic nanoparticles were measured with the magnetometer developed, giving an error percentage lower than 2% in the firsts case. Details of the assembly and operation of the magnetometer are presented.

Keywords: Faraday magnetometer, automation, Verdet constant, IEEE488 port

Topic: Opto-mechanics and hybrid systems

Figure 1. Experimental setup of the Faraday magnetometer for measuring the Verdet constant of water.
TRANSFER MATRIX FOR INVESTIGATING STRUCTURAL COLOURS IN BIOLOGICAL SYSTEMS

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Many biological systems are known to use structural colour effects to generate aspects of their appearance and visibility. The skin, scales, feathers, and fur of animals can be coloured by the deposition of pigments or through the physical interaction between light and nanostructural components of the integument. Both mechanisms of colour production are widespread in birds. Colours produced by feather nanostructures, termed structural colours, can be further subdivided into iridescent and non-iridescent colours. Broadly defined, iridescent structural colours change in appearance with the angle of observation or illumination, while non-iridescent colours generally remain similar in appearance regardless of viewing geometry. Iridescence is produced by coherent scattering of light waves from alternating layers of materials of different refractive indices. The structure and organization of these layers, and hence the appearance of bird species with different types of plumage, varies extensively. One principal distinction between different types of iridescent colour is whether they are produced by a single pair of layers or by multiple pairs of layers. In this work, we first explain the fundamental optical properties underlying the structural colours, and then survey these mysteries of nature from the viewpoint of regularity and irregularity of the structure. A thin-film model based on the thickness of the keratin layer and its two associated interfaces (air/keratin and keratin/melanin) generates predicted reflectance spectra. Consider a plane wave of light that is incident on a thin layer of thickness $d$ and an refractive index $n$. We used a standard transfer matrix thin film optical model to determine how iridescent colour is produced. We used this model to predict the reflectance spectra and optical properties of keratin and melanin layers, allowing us to evaluate the relative importance of these layers and providing insight into how variation in each might affect colouration. We have overviewed the mechanisms and distributions of the structural colors from a viewpoint of regularity and irregularity within their structures. As result, we can classify the structures as colors in two categories according to their structural origins. First, they originate from regular structure, which has a dimension slightly less than the wavelength of light, and the irregular structure, which is much larger than the former and contributes to emit the diffusive light.

References:
Optimal Optomechanical Cooling Under Non-Markovian Evolution

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Potential quantum technologies or exploration of quantum effects require ground-state preparation. Therefore, it is of great interest to search different schemes that can improve the efficiency of cooling protocols in the context of quantum optomechanical setups. Schemes proposed recently are performed under Markovian processes. However, due to the temperature and the fact that the scales at which cooling take place are very short, of the order of the period of the resonator, it is expected that non-Markovian effects of interaction among the resonator and the environment dominate the energy transfer and the entropy between them. These elements are incorporated in the present work by considering non-Markovian processes that are closer to reality and recent experiments have demonstrated evidence of non-Markovian effects in mechanical systems. One of techniques to reach the minimum phonon number is to find an optimal coupling function between the mechanical resonator and the optical mode in a Fabry-Perot cavity via optimal control theory. Applying this technique and introducing the non-Markovian character in the sideband cooling, we found that the minimum phonon number in the resonator is lower than the predicted by Markovian processes. For large coupling strengths, where the rotating-wave approximation fails, the minimum phonon number depends on the time evolution and the maximum value of coupling strength of the optimal coupling function. Finally, we apply a methodology to maintain the minimum phonon number achieved along a large number of periods of the mechanical resonator.
Effect of rare earth additives on the microstructure and dielectric properties of PLMN-PT ceramics

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The transparent relaxor ferroelectric ceramics of the system lanthanum modified lead magnesium niobate (PLMN-PT) have been investigated for a variety of electro-optic properties; good electro-optic switching times and modest half-wave voltages, however, the dependence of microstructural and dielectric properties in function or rare earth has not been reported. Microstructure and dielectric properties of PLMN-PT ceramics doped with RE (RE = Tm, Nd, Yb), have been investigated. The effects of these dopants on microstructure, maximum dielectric constant (Kmax) and degree of ordering, etc. have been studied. It was found that doping of Nd and reduced Kmax, while the doping of Yb increased Kmax. The variation of Kmax is analyzed according to grain size, domain structure and order–disorder behavior. Diffuseness of the phase transition is calculated to indicate order–disorder behavior, which is roughly opposite to that of Kmax.
Exciton ground state in a GaAs/AlAs type II nanowire

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In type-II superlattice structure unlike to type-I, the lowest energy transition is indirect in real space, the electron and hole are confined to separate layers and the electrical and optical properties of type-II structures are very different from their type-I counterparts. In this report we present an exciton ground state theoretical study confinement in a type II nanowire, with cylindrical geometry, formed by GaAs/AlAs layers in the effective mass approximation and an applied magnetic field in growth direction (axial direction). In this structure the electron and hole are confinements in the AlAs layer and GaAs layer, respectively. The potential confinement is infinity in radial direction and finite in axial direction, the last one is given by the difference of the band gap between both materials. In this report is analyzed the effect upon exciton ground state energy due to the magnetic field and size of the structure.
Analytic derivation of the Maxwell stress tensor of spherical lipid vesicles under alternate electromagnetic fields

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The cell is a system with mechanical, electric, and chemical activity. The cell can be affected by external influences such as electromagnetic fields and modify mechanical and electrical properties of the cell. A model to mimic the cell membrane is a vesicle. This is a good approximation in the way to obtain a complete understanding of the mechanical properties of the plasmatic cell. The Maxwell stress tensors provide the force per unit of area over a surface due to an external electromagnetic field. This tensor is the key point to obtain the mechanical response of the vesicle. In this work we present an analytic method that can be easily generalized to a system of one monolayer and systems even more complex than the bilayer, that is, a spherical arrangement of bilayers. We show that components of the tensors depend on frequency of the external electromagnetic field and the ratio of the internal and external conductivities. This model predicts previous experimental results for the change in shape of a monolayer and bilayer. In the case of a double bilayer the behavior it much complex and no experimental data exist -as far as we know- to compare with. This work we provide a manner to obtain superficial effects such as phenomena of electro-diffusion, electro-rotation, and electro-deformation used by experimental researchers to study the cell, the neuloide or other organelle.
Study of Induced Birefringence in Microstructures Based in Azopolymer by Two-Photon Polymerization

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In this research was conducted a study of the optically induced birefringence in the azopolymer Hema-HDR13. Generating anisotropy in the material through the photo-spinorization process for azo-compounds, the chromospheres are reoriented in the material through an external electric field, from an Nd: YAG laser, emitting with a wavelength of 532 nm. Based on an absorption spectrum of azopolymer samples was determined that the wavelength at which the phenomenon begins. Measurements were made to determine the degree of birefringence and thus determine which of them can be used as material to design optical storage devices. Also was analysed the theoretical models of photo-molecular orientation, and succeeded in identifying which of them corresponds to the results and establishing the characteristic times appearing in each for Hema-DR13.