INTERNATIONAL CONFERENCE ON PHYSICS OF LIGHT-MATTER COUPLING IN NANOSTRUCTURES -PLMCN 2023-

April 11th-16th

MEDELLÍN, COLOMBIA

PLMCN

MDPI

Mediterranean Institute of Fundamental Physics

UNIVERSIDAD DE ANTIOQUIA

Uptc Universidad Pedagógica y Tecnológica de Colombia

Universidad de Córdoba

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A message from the organisers

Dear participant of PLMCN23, welcome to Medellín!

The venue for International Conference Physics of Light-Matter Coupling in Nanostructures (PLMCN) returns to Medellín after eight years. Once again, interesting and newfangled scientific results in hot areas such as polaritons, quantum nanostructures, and photonics will be discussed within an environment of typical Colombian hospitality at the University of Antioquia, from April 11th to 16th 2023. Contributions include a total of 39 oral presentations, of which 17 are invited talks; and 24 posters.

For the local organizing committee, it is very satisfying to have in Colombia and Medellín the participation of leading researchers of world prestige in the International Conference on Physics of Light-Matter Coupling in Nanostructures, the interaction with the Colombian students will allow us to achieve the objectives of this event: Highlight the importance of photonics as a strategic tool in the development of new materials, interfaces, devices and functional systems focused on energy conversion and environmental remediation. Review recent achievements in the fundamental understanding of strong light-matter coupling. Evaluate the progress in the development of technologies for the growth of epitaxial heterostructures. Know the industrial process of wide gap semiconductors, organic nanostructures. Establish the state of the art in the technological development of microcavities as the basis for optical applications.

The first PLMCN conference has been organized in St-Nectaire, France, in 2000. Since then the conference visited Rome, Crete (twice), Acireale, St-Petersburg, Glasgow, Magdeburg, Havana, Tokyo, Montpellier, Lecce, Berlin, Hangzhou, Medellín, Würzburg, Moscow, Suzdal, and Clermont-Ferrand (online). The PLMCN conference series is unique because of the strong focus on cultural, social and gastronomic events that help informal *getting-together* of the conference participants. In the turbulent 2020s it remains one of those tiny links that keep the scientific world together.

We welcome you on behalf of the Colombian universities: *Universidad de Antioquia* (Álvaro Morales and Carlos Duque), *Universidad Pedagogica y Tecnologica de Colombia* (Judith Ojeda), *Universidad del Magdalena* (José Sierra), *Universidad de Córdoba* (Luis Alcalá) and *Universidad EIA* (Ricardo Restrepo). From Mexico, *Universidad Autónoma de Zacatecas* (Karla Arely Rodríguez and Juan Carlos Martínez)

Yours sincerely,

Conference and Program Chair
Prof. Alexey Kavokin (Westlake University, China)
Conference and Program co-chair
Prof. Carlos Duque Echeverri (Universidad de Antioquia, Colombia)
Scientific Secretary
Dr. Helgi Sigurðsson (University of Iceland, Iceland)

PLMCN23 CONFERENCE PROGRAM

Tuesday, April 11th

09:00 Registration

Excitons and Polaritons in 2D Materials

09:30 Wei Bao (invited talk)
Exciton-polaritons with halide perovskites

10:15 Daniel Suarez-Forero
Spin-selective light-matter coupling of a 2D hole gas-microcavity system in the Quantum Hall regime

10:30 Coffee break

Optics of 1D structures and Quantum Dots

11:00 Carlos Antón Solanas (invited talk)
Quantum dots in III-V semiconductors and in 2D crystals: a new generation of efficient quantum light sources

11:30 Lukas Husel
Telecom-band single photons from functionalized carbon nanotubes coupled to an open cavity

11:45 Jaime David Díaz Ramírez
Composed effects of electron-hole exchange and near-field interaction in quantum-dot-confined radiative dipoles

12:00 Coffee break

12:15 Nika Akopian (invited talk)
Multi-qubit photonic devices

12:45 Viktor Tulupenko
Electric field influence on intraband transitions in delta-doped quantum wells

13:00 Lunch

Plasmonics, Metamaterials, Novel optical devices

15:00 Morten Willatzen (invited talk)
Piezoelectric Control of Acoustic and Optical Properties

15:30 Johannes Scherzer
Magneto-Optical Chirality in a Coherently Coupled Exciton–Plasmon System

15:45 Oscar Restrepo Gutierrezor
Effects of high pressures on the structural properties of the GeO_2-PbO glassy system with incorporation of Au nanoparticles for applications in optoelectronic devices

16:00 Raul Esquivel-Sirvent
Tuning radiative heat transfer via surface-polaritons hybridization

16:15 Juan Diego Garro Catano
Effects of quantum confinement in Ag nanoparticles on the spectroscopic properties of the Pr3+ ion doped in germanate glass

16:30 Sergio Castrillon Salazar
Dual band generation and wavelength-switchable fiber soliton laser mode-locked based on monolayer graphene

18:00 Welcome reception

Wednesday, April 12th

Exciton-polariton Bose-Einstein condensates

09:00 Antonio Gianfrate (invited talk)
BIC Exciton-polariton condensate

09:30 Alexey Yulin (invited talk)
The effect of the rotating potential on the resonant and non-resonant interactions in the annular polariton condensates

10:00 Dmitrii Dovzhenko
Next nearest neighbour coupling in exciton-polariton condensates

10:15 Luisa Toledo Tude
A model for thermodynamic analysis of polariton condensation

10:30 Coffee break

Excitons and Polaritons in 2D Materials

11:00 Ivan Shelykh (invited talk)
Light-matter coupling in CrI_3 magnetic monolayers

11:30 Hui Deng (invited talk)
Unconventional Polariton in Van der Waals Semiconductors

12:00 Coffee break

Optics of 1D structures and Quantum Dots

12:15 Sven Höfling (invited talk)
Circular Bragg grating cavities for semiconductor quantum dot based quantum technologies

12:45 Jose Carlos Leon Gonzalez
Influence of a non-resonant intense laser and topological defect on the electronic properties of a GaAs quantum ring under inversely quadratic potential

13:00 Lunch

Exciton-polariton Bose-Einstein condensates

15:00 Michael Fraser (invited talk)
Optically driven rotation of exciton-polariton condensates

15:30 Roman Cherbunin (invited talk)
Quantization of exciton polaritons in shallow optical traps

16:00 Yannis Balas
Stochastic Single Shot Polariton Condensate Polarization Pinning at High Temperatures

19:00 Conference banquet

Thursday, April 13th

Excursion (Starting at 7:00 AM)

Friday, April 14th

Non-Hermitian and Topological physics

09:00 Alexander Khanikaev (invited talk)
Topological polaritonic structures based on patterned bulk transition metal dichalcogenide WS2 crystals

09:35 Sebastian Klembt (invited talk)
Topological insulator vertical-cavity laser array: From fundamental aspects to potential application

10:10 Luciano Ricco
Reshaping the Jaynes-Cummings ladder with Majorana bound states

10:30 Coffee break

Spintronics and exciton spin-related phenomena

11:00 Alexey Akimov
Gyroscope based on NV center in Diamond

11:15 Erika Soto
Catechol aromatic molecular system used as a spintronic device

11:30 María Paula Rojas Sepúlveda
Effects of the exciton fine structure splitting on the entanglement-based quantum key distribution

11:45 Coffee break

Exciton-polariton Bose-Einstein condensates

12:15 Matthias Wurdack (invited talk)
Engineering the properties of exciton polaritons in an atomically-thin semiconductor

12:45 Ivan Gnusov (invited talk)
Quantized vortex formation in the "Rotating Bucket" experiment with nonlinear fluids of light

13:15 Lunch

15:30 - 17:00 Poster session

Saturday, April 15th

Exciton-polariton Bose-Einstein condensates

09:00 Eliezer Estrecho (invited talk)
Collective excitations of high-density optically trapped exciton-polariton condensates

09:30 Sergey Alyatkin (invited talk)
Towards lattices of interacting polariton condensates carrying vorticity

10:00 Anna Grudinina
Spectrum of elementary excitations of bound-in-the continuum polariton Bose condensate in a waveguide

10:15 Dogyun Ko
Observation of a single quantized vortex vanishment in exciton-polariton superfluids

10:30 Coffee break

Plasmonics, Metamaterials, Novel optical devices

11:00 Mikhail Portnoi (invited talk)
Optovalleytronics with warped or tilted Dirac cones

11:30 Hernán Gómez-Urrea
Tunable photonic band gaps in two-dimensional Bravais-Moiré photonic crystal composed of copper oxide high-temperature superconductors

11:45 Omer Cohen
Electrically-Driven Plasmons in Metal-Insulator-Semiconductor Tunnel Junctions: The Role of Si Amorphization

12:00 Best student talk and poster award
12:15 Conference closing

Posters

Andrés Mauricio Bernal Forigua
Improvement in the conductivity of transparent conductive silver nanowire thin films through thermal and mechanical processes

Anna Sofia Giraldo Neira
Adsorption of small molecules on defective phosphorene

Carlos Alberto Dagua-Conda
Influence of hydrostatic pressure and magnetic field on electronic transport properties in GaAs/AlGaAs finite superlattice considering geometric modifications

Clara Lilia Calderón
Growth and characterization of Bi_2S_3 thin films for application in solar cells

Daniel Ruiz Mejía
Optical response of Harmonic gaussian well under the effect of an electric field

Fernanda Mora Rey
Electric and magnetic field effects in vertically coupled conical quantum dots

Eylin Acosta-Jimenez
A survey of Photocatalytic effect of ZnO/SnO_2 over methylene blue samples

Gene Elizabeth Escorcia SalaHanzs
Optical properties in a conical-shape core/shell quantum dot with a wetting layer: Effects of an electric field and temperature

Gerardo Jafet
Electronic structure and absorption coefficient for 2D GaAs doped with Si, Ge and Sn amphoteric impurities: A DFT study

John Alexander Gil-Corrales
Self-consistent study of GaAs/AlGaAs quantum wells with modulated doping

John Fernando Zapata Mesa
Optical properties of impurities in GaAs spherical quantum dots under the Kratzer potential

Jose de Jesus Alvarado-Goytia
DFT studies of the borophene basic optoelectronic properties doped with aluminum and gallium substitutional atoms

José Sierra Ortega
Energy spectrum of an exciton in a type II core/shell quantum dot. Effects of intense non-resonant laser radiation

Juan Alejandro Vinasco Suárez
Spin Orbit Interaction and Zeeman effect contributions to electro-optical properties in a double quantum ring

L. Germán Daza
Layers and multilayers of ITO, AZO and ITO/AZO thin films grown by RF magnetron sputtering for the adjustment of their optical properties

Lucero Álvarez Miño
Non-zero Magnetoresistance at Room Temperature for a Manganite Tunneling Junction

Luis Arturo Alcalá Varilla
Effects of self-interactions of Coulomb over the relative stability of small copper clusters: Phonon calculations

Marco A. Tun-Carrilloa
Features of light propagation in Rudin-Shapiro-based hybrid dielectric heterostructures

Miguel Eduardo Mora-Ramos
Intersubband optical responses in semiconductor quantum wells with non-conventional confining potentials and spatially-dependent effective mass

Rafael Guillermo Toscano Negrette
Effect of external fields on the electronic and optical properties in ZnTe/CdSe and CdSe/ZnTe spherical quantum dot

Ricardo León Restrepo Arango
Nonlinear optical absorption coefficients in elliptical Core/Shell/Shell quantum dots: Effects of electric and magnetic fields

Tomas Sosa Giraldo
Nonlinear optical properties in hexagonal GaAs/GaAl 0.3 As 0.7 quantum wires: Donor impurity, electric, and magnetic field effects

Waira Murillo-Garcia
Narrow band filters designed from hybrid quasi-periodic photonic crystals with a single defect layer

Yineth Melissa Pérez Ayala
Copper nanowires synthesis for transparent conductive thin films

Topological polaritonic structures based on patterned bulk transition metal dichalcogenide WS2 crystals

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Topological photonic systems attracted a significant deal of attention due to the possibility to control electromagnetic waves in a unique way, e.g., via artificial degrees of freedom (pseudo-spins), and thanks to robust trapping and guiding they offer. These intriguing optical properties made topological photonic crystals promising for studying light-matter interactions. In this context several demonstrations of topological polaritons were made in different platforms, including semiconductor quantum dots and quantum wells [1-3], and photonic nanostructures integrating 2D and van der Waals materials, transition metal dichalcogenides (TMDCs) [4,5] and hexagonal boron nitride [6] specifically. The latter classes of materials can be easily integrated into photonic topological structures by their direct transfer, however, the lack of low-loss and high refractive index substrate materials at shorter visible wavelengths makes this approach less fruitful, and one needs to sacrifice between loss and the degree of the mode confinement by choosing to work with lower index membranes (e.g., SiN), which are also difficult to fabricate, pattern, and handle.

Recently, bulk TMDCs themselves have been successfully used as high index substrates for direct patterning and several optical nanostructures with moderate loss and desired functionality were reported [7-9]. For polaritonics, direct patterning of bulk TMDCs may also offer the opportunity to couple excitons and photonic modes bypassing the need of patterning any substrates. In this work we designed and experimentally realized a polaritonic topological insulator based on bulk TMDC (~40nm-thick WS_2 film). WS_2 flakes were exfoliated and transferred on top of a thermal 1μm-thick SiO_2 on Si substrate and then patterned using electron beam lithography and reactive ion etching to produce a set of lattices corresponding to a spin-Hall type of topological insulator (Fig. 1a). The structure was subsequently characterized by back focal plane imaging, and the presence of the exciton line, the bulk bands and of topological polaritonic boundary modes in the bandgap region was confirmed (Fig.1b-c).

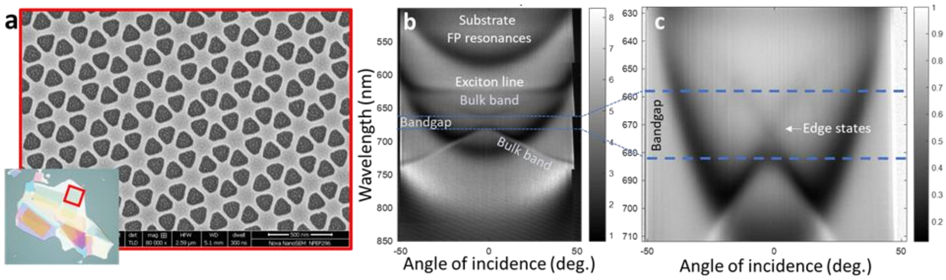

Fig. 1: a, SEM image of topological polaritonic crystal implemented by direct patterning of WS2. Inset on the bottom shows the flake with the region of the crystal in SEM highlighted in red. **b** and **c**, band structures of polaritonic topological crystal obtained by back focal plane imaging with excitation in the bulk topological region (**b**) and at the topological domain wall (**c**), respectively.

References

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Gyroscope based on NV center in Diamond

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A rotation sensor is one of the key elements of inertial navigation systems. Among such applications is inertial navigation, which becomes more and more demanded with development of unmanned and autonomous vehicles. At the absence of global navigation system (GPS) signals, for example, inside buildings or tunnels and under water or ground, such vehicles must rely on inertial navigation and in particular rotation sensors.

The precision of a gyroscope varies a lot depending on its form-factor and principle of operation. The records for precision and bias stability of industrially available gyroscopes are traditionally held by mechanical, ring-laser, and fiber-optic gyroscopes. The first one is large and massive device, the latter two are based on the Sagnac effect, their precision is proportional to the surface enclosed by the optical light path. While there has been great progress in miniaturization of this type of device, fundamental limits, related to the size and sensitivity of the device, are still hard to overcome. On the other hand, much less precise microelectromechanical system (MEMS) gyroscopes are widely used for mass production in consumer electronics. While the bias stability of these devices is often not sufficient for robust long-term inertial navigation, these devices have excellent power consumption characteristics, chip-scale dimensions, and low prices.

Despite enormous progress in improving the bias stability and precision of MEMS devices, there is still a considerable gap between compact and precise devices. A possible approach to miniaturizing gyroscopes while maintaining high precision is to use nitrogen-vacancy (NV) center in diamond, which has demonstrated excellent properties as a solid-state spin system. It possesses optically detectable electron spin, with a long coherence time at room temperature and means for optical polarization of the spin state. Besides, it possesses nuclear spin of the nitrogen atom, which has much smaller gyromagnetic ratio, then electronic spin, and thus is more suitable for rotation measurements.

Here, we carry out a proof-of-concept experiment, demonstrating rotation measurements on a rotating setup utilizing nuclear spins of an ensemble of NV centers as a sensing element with no stationary reference. The electron spin is used to initialize and readout nuclear spin state as well as to measure magnetic field and the temperature of the diamond. The reading of the nuclear spin is corrected on the effect of a magnetic field thus allowing to extract pure rotation signal. The measurement is verified by a commercially available MEMS gyroscope.

The effect of the rotating potential on the resonant and non-resonant interactions in the annular polariton condensates

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In resent time it was experimentally shown that rotating potential results in the selection of the winding number of the polariton condensates forming in the annular systems [1]. In the same work the experimental results were reproduced by numerical simulations based on the model describing the condensates by partial differential equation for the order parameter function coupled to the ordinary differential equations for the exciton densities in the active and inactive reservoirs. Later the polarization dynamics of the condensates in the rotating traps were considered in the conservative limit in [2] where it was demonstrated that the rotation of the potential can lead to the effect analogues to the electronic magnetic resonance. In this work we study systematically the effect of the rotation potential on the stationary states of the polariton condensates forming in the annular traps in the presence of the incoherent pump. To describe the system we eliminate the equations for the reservoirs adiabatically and derive the equations for circularly polarized components of the condensate. In dimensionless units the equations read

$$\partial_t \psi_\pm = \frac{i}{2}\nabla^2\psi_\pm + i(V+U)\psi_\pm - iU|\psi_\pm|^2\psi_\pm - i\left(\alpha|\psi_\pm|^2 + \beta|\psi_\mp|^2\right)\psi_\pm,$$

where $\psi_\pm$ are the order parameter functions for clock and counter-clockwise polarizations, the effect of the spatially non-uniform cavity resonant frequency and losses is accounted by the complex potential V, the incoherent pump creating the gain and the polariton blue shift is accounted by the potential U, the third term in the right hand side describes the effect of the reservoir depletion and, finally, the last term describes the effect of the polariton densities in the same (α) and in the opposite (β) polarizations on the resonant frequency of the polarization. We consider the case of azimuth symmetric potential V and the potential U being an evenly rotating harmonic function of the angular coordinate.

We start with the scalar case and focus on the pump intensities close to the lasing threshold. We derive nonlinear equations for the mode amplitudes and show that this description reproduces well the dynamics observed in the numerical simulations of the 2D partial differential equation. In particular we explain the dependency of the average angular momentum of the polariton condensate on the rotation velocity of the trap. We also address the effect of the resonant frequency blue shift on the angular momentum of the condensates.

Then we generalize the results to the vector case describing the polarization dynamics of the condensate. In particular we consider the effect of the rotation induced spin resonance on the polarization structure of the polariton condensates forming in those systems. It is shown that in this case the stationary state is a rotating dipole-like structure in one circular polarization and a slightly perturbed vortex in another circular polarization. It is shown that the rotation of the potential is a powerful tool to control both the angular momentum and the polarization of the exciton-polariton condensates.

References

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Improvement in the conductivity of transparent conductive silver nanowire thin films through thermal and mechanical processes.

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The wide expansion of optoelectronic devices has produced the massive exploitation of different materials and the achievement of new ones. Some of those demand conductive materials which on being synthesized in thin film shape have as high charge carrier density as possible in its conductive band while allow the transmission of visible light, that means, conductive and transparent layers that can be used as transparent electrodes in devices like solar cells, LEDs, OLEDs and touch screens. Currently, the ITO (Indium Tin Oxide) has been used to this propose, a composition which has some drawbacks, like the fact that Indium is a scarce element and the films have ceramic properties that make them useless in flexible devices. For that, it is necessary to find out a new alternative to replace it [1,2].

Some candidate are organic and nanostructured materials. By our side, we have worked with silver nanowires (Ag NW) to make thin films obtaining promising results. We fabricated the Ag NW films by the Spin Coating process, which is a cheap and easy method [2,3]. One of the purposes is to find the best parameters of film fabrication, here each film was made with a quantity of three drops of material dissolved in ethanol, scattered over the glass substrate by rotation with an angular frequency of 3000RPM for 3 min at room temperature. Just a solvent fraction is evaporated in the processes of rotation; therefore, the films are dried at 100 °C during 10 min. After fabrication, the films are characterized as follows: the electrical properties were measured by four-point probe technique, finding sheet resistances lower than 30 Ω/sq, the optical properties by transmittance which gave an average value of 75% at 550 nm wavelength and the morphological and structural properties with SEM [3]. These results allow us to augur the nanostructured films as promissory candidates to replace the ITO.

Despite these results, there are some drawbacks to solve, for example, the high contact resistance between nanowires. Because of this last, we have probed two different extra processes to try to improve the electrical contact between the nanowires conforming the thin film. This processes pretend as well getting more homogenous films without affecting its light transmittance [4]. The first one is the nanowire welding by heat treatment. In this method the films are exposed to high temperatures (120-190 °C) during different time intervals, achieving a kind of junction in some of the contacts and reducing the sheet resistance in a percentage magnitude of up to 50%. In this process it was observed the nanowires degradation after a certain temperature. The second applied method is the application of pressures on the films; in this method, we applied a force between 2 and 10 Ton-Force during different time intervals over the films surface achieving a sheet resistance decrease in a percentage magnitude of up to 76%. The results show an important improvement in the electrical conductivity of the metallic nanowire films after the welding processes without apparent variations of thin film transmittance.

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Spectrum of elementary excitations of bound-in-the continuum polariton Bose condensate in a waveguide

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Bound-in-the-continuum states, firstly proposed as the solution of the Schrödinger equation with a potential of a special shape, are observed in a wide range of physical systems and in optical waveguides, in particular [1]. In waveguides with periodic grating, bound states in the continuum appear due to the coupling between two counter propagating modes of an electromagnetic wave resulting in the formation of two new modes, one of them being bright and the other dark, with zero imaginary part of energy at zero momentum. In the recent work [2] it was shown that in a waveguide, exciton-polaritons resulting from coupling between excitons and the dark photon modes demonstrate the dispersion law of a peculiar shape which is a saddle around the point $k = 0$ instead of the standard paraboloid. Nevertheless, in this system the polariton Bose condensation is observed, and the condensate is populated in the saddle point (not in the points of global minima of the dispersion) due to the (quasi-)infinite polariton lifetime at $k = 0$ which provides conditions for the condensate formation.

In our work we apply the Hartree-Fock-Bogoliubov theory for exciton-polaritons that self-consistently takes into account finite temperatures and the presence of dark excitons [3], and calculate the Bogoliubov excitation spectrum for exciton-polaitons in the waveguide (Fig. 1). The obtained dispersions, being in a good agreement with the experimental data, are highly anisotropic and demonstrate flattering of the dispersion along k_y -direction at near-zero k_x and the formation of a local minimum at $k_x = 0$ (Fig. 1b,c). We show that the two-lobe pattern in photoluminescence maps in the (k_x, k_y) domain, characteristic of waveguides with gratings, has a “fine structure” which is reproduced by the theoretical (k_x, k_y) cross-cuts of the Bogoliubov dispersion at given energies.

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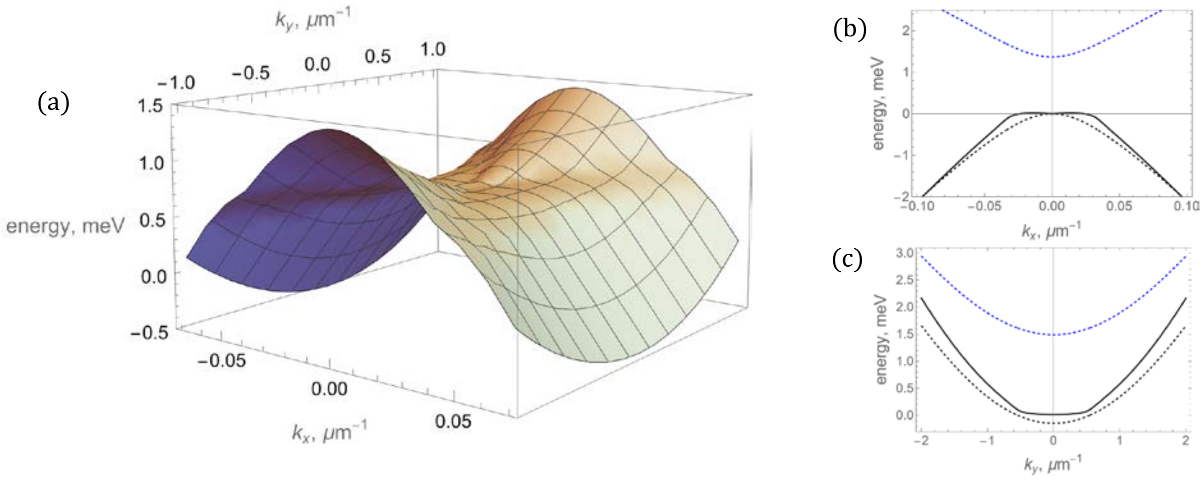

Fig. 1: (a) Theoretically calculated Bogoliubov dispersion of excitations on top of the saddle-point polariton condensate; (b-c) Cross-cuts of the Bogoliubov excitation spectrum (black solid line), the upper and lower polariton dispersion (blue and black dashed lines, respectively) at (b) $k_y = 0$, (c) $k_x = 0.02\ \mu m^{-1}$.

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Adsorption of small molecules on defective phosphorene

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In recent years, the study of the optoelectronic properties of two-dimensional materials has occupied the scientific community's attention due to their physicochemical properties that make them excellent candidates for the development of different optoelectronic devices. The opto-electronic properties of two-dimensional materials can be modified by structural defects and by the adsorption of small molecules such as H2, O2, CO, NO, and others.

Of the broad spectrum of two-dimensional materials, phosphorene is an allotrope of phosphorus that can be obtained by mechanical exfoliation of black phosphorus. Unlike graphene, phosphorene is a semiconductor with a bandwidth that the number of layers can modulate.

Motivated by the above, in this work, the effects of the adsorption of small molecules on the opto-electronic properties of defective phosphorene. All calculations are performed using density functional theory (DFT) as implemented in the SIESTA package [1]. The van der Waals interaction is considered for the exchange-correlation functional [2]. A 5x7 size supercell was taken, where all the structures were completely relaxed with a maximum force of 0.02 eV/Å. Furthermore, several positions of the molecules are considered. To define were is the most probable adsorption position, the adsorption energy is considered.

The results indicate that the structural defect induces changes in the adsorption energy mainly due to the redistribution of charge induced by the vacancies. However, these adsorption energies are small compared with other 2D materials.

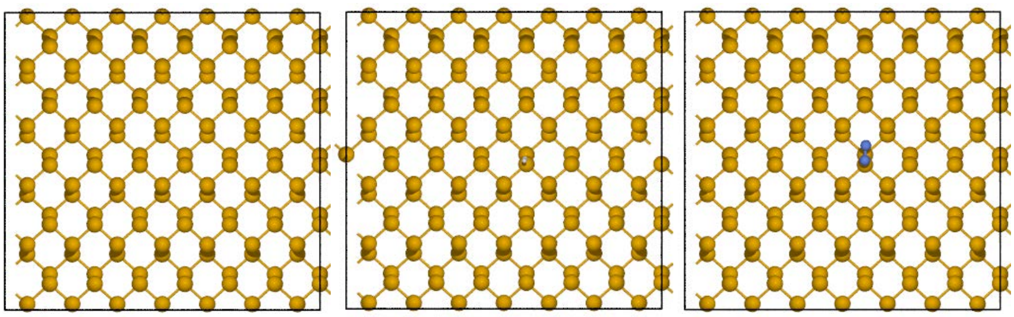

Fig. 1: Relaxed phosphorene structure, with a H^2 molecule in top position, and a N^2 molecule in top position, respectively.

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BIC Exciton-polariton condensate

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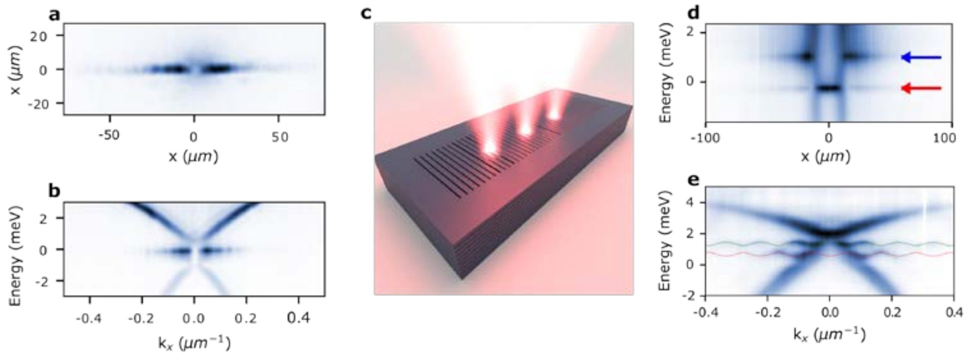
Optical bound states in the continuum, or BICs, are a unique type of topological state that are protected from radiating in the far field while existing within the light cone. In previous study, we demonstrate Bose-Einstein condensation of polaritons in a BIC.

Interestingly, the BIC causes polaritons to condense in the extremum of a negative mass dispersion, leading to strong interaction-induced trapping at the pump spot and therefore in the maximum gain region. We exploit this optical self-trapping mechanism to demonstrate macroscopic mode-hybridization, enabling the construction of artificial BIC molecules with unusual topological charge multiplicity.

We also demonstrate the flexibility of the optical write-in approach by constructing artificial mono-atomic and dimerized BIC chains of polariton fluids displaying non-Hermitian quasicrystalline band formation and gap opening.

The large interaction strength of exciton-polaritons in subwavelength quantum-well waveguide gratings in conjunction with their topologically protected BIC nature opens unexplored opportunities in low-threshold optically reprogrammable non-Hermitian quantum fluids.



Optically imprinted BIC lattices: a) and b) show the real space photoluminescence distribution and the energy momentum dispersion for a single BIC condensate. c) artistic representation of the grated waveguide sample non resonantly excited with multiple non-resonant spots. e) energy resolved real space crosscut of the BIC molecule showing the modes hybridization d) energy-momentum dispersion showing the minibands formation for a staggered lattice excitation scheme

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Influence of hydrostatic pressure and magnetic field on electronic transport properties in GaAs/AlGaAs finite superlattice considering geometric modifications

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During the resonance splitting effect, the resonance energies induced by the tunneling split gradually as the periodic superlattice (SL) increases, which would eventually form the minibands responsible for transport properties of semiconductor SLs such as the Bloch oscillations or the Stark ladders phenomena [1]. The SLs configurations of barriers and wells are essential for properties of electronic transport, and geometric variations introduce symmetric and asymmetric in the length of the SL period [2]. The influence of external fields on the semiconductor SL includes the smooth potential barrier model, in which it is possible to modify the properties of electronic transport, in particular, the current-voltage curves [3]. However, the specific roles of geometric variations and the influence of external fields, including the hydrostatic pressure on the semiconductor SL during the process of electronic transport remain unknown.

Here we present that the finite periodic SL of the semiconductor material GaAs/AlGaAs drives the tunneling current depending on the geometric variations of the heterostructure. We found that the influence of the electric, and magnetic fields, and the hydrostatic pressure over the GaAs/AlGaAs SL has the remarkable capacity of simultaneously displacing the coherent resonant tunneling and modulating the amplitude of the transmission probability. Furthermore, we found that using the Landauer-Buttiker formalism, the current due to the tunneling electrons from the emitter to the collector generated by a potential difference between the terminals of the device results in control of the negative differential resistance, suggesting an additional improvement in the current-voltage characteristics.

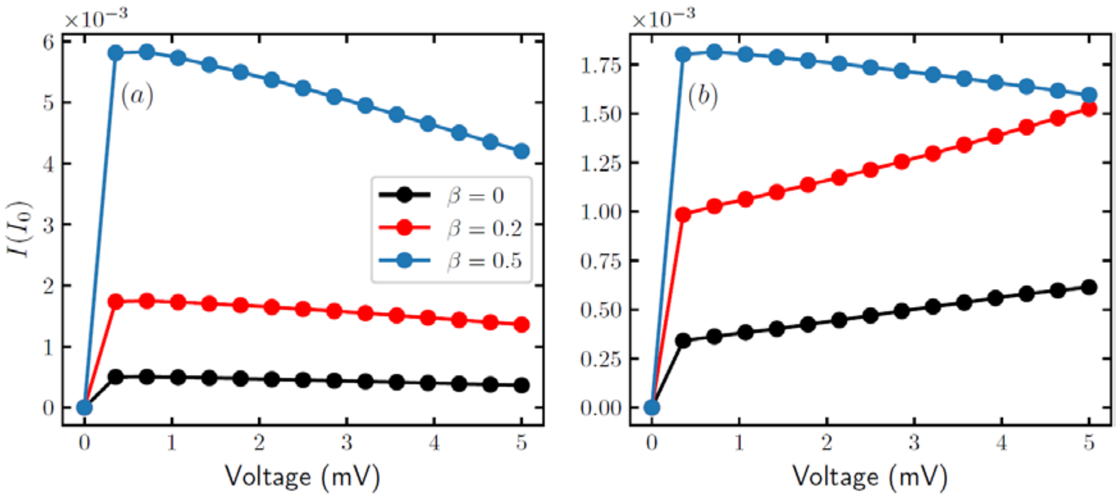

Fig. 1: The electronic tunneling current for the well-barrier lattice system as a function of the bias voltage, magnetic field (B), hydrostatic pressure (P), and geometric parameter β. In (a), B=0 T, P=0 kbar. In (b), B=5 T, P=20 kbar.

fig1.pdf

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Quantum dots in III-V semiconductors and in 2D crystals: a new generation of efficient quantum light sources

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An optimal single-photon source fulfils the following triple benchmark: (I) **Brightness**: it delivers a single-photon Fock state deterministically "at the push of a button" (and never vacuum); (II) **Purity**: it always generates a photon number Fock state (and never multi-photon Fock states); (III) **Indistinguishability**: all the emitted single-photon Fock states are identical, and thus, they perfectly interfere as bosons (displaying the Hong-Ou-Mandel effect).

In the first part of this talk, I will discuss the state-of-the-art on near-optimal single-photon emitters [1], based on III-V semiconductor quantum dots in cavities. In this context, I will discuss my recent results on this platform to generate quantum states of light beyond single-photon Fock states, such as superposition and scalable multipartite time-entanglement in the photon number basis [2,3].

In the second part of this talk, I will discuss a disruptive platform to generate single photons based on atomically thin WSe_2 monolayers. The local strain in these monolayers produces a potential capable to trap single excitons and so produce single-photon emission [4]. These quantum dots can be coupled to open optical cavities, enhancing their performance towards competitive single-photon sources. First quantum communication testbed-applications with atomically thin WSe_2 quantum dots are being implemented [5], promising a "bright future" for these emergent emitters.

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Growth and characterization of Bi_2S_3 thin films for application in solar cells

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The chalcogenide materials such as SnS, SnS_2, Sn_2S_3 and Bi_2S_3 are of great current interest due to its applications in the fabrication of optoelectronic, thermoelectric and photovoltaic devices, and as a holographic recording medium. This interest is because the S and Sn are inexpensive, abundant in nature and less toxic than most of the materials used in the industry for manufacturing these types of devices. Particularly, the SnS presents suitable properties for its use as absorbent layer in solar cells with conversion efficiencies of up to 25% theoretically [1]; the Bi_2S_3 is widely studied because of its physical and chemical properties, suitable for the development of solar cells, luminescent devices, pigments, IR detectors, and thermoelectric devices [2, 3].

The performance of a solar cell depends on the characteristics of each of the materials that constitute it, being its optical properties one of the most relevant aspects, solar cells must respond adequately to the spectrum of solar radiation. In this work we present results related to the optical behavior of Bi_2S_3 thin films varying the Bi content. The films were grown by sulfurization of the metallic precursors on a soda-lime glass substrate and characterized through X-ray diffraction and transmittance measurements. The results showed an optical gap between 1.27 and 1.37 eV, an absorption coefficient (α) of the order of 10^4 cm^{-1} and a refractive index between 2.2 and 6.4. These results indicate that this type of compounds are suitable from the point of view of their optical properties for the manufacture of solar cells such as the one outlined in Figure 1.

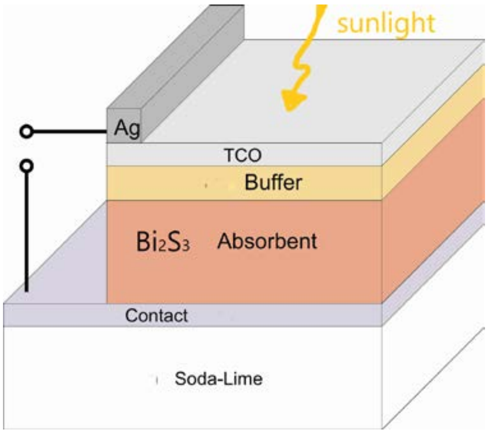

Fig. 1: Schematic drawing of a thin-film solar cell using Bi_2S_3 as an absorbent layer.

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Optical response of Harmonic gaussian well under the effect of an electric field

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In this paper, a theoretical study of an electron in a harmonic gaussian potential is performed. In order to obtain the electronic states, the Schrödinger equation is solved by means of the numerov method, considering the parabolic band and effective mass approximations. Additionally, the optical absorption coefficient is calculated and the effects of an external electric field and the geometrical parameters of the potential are analyzed. The results show that the electron spectrum strongly depends on the form of the potential as well as on the intensity of the applied electric field.

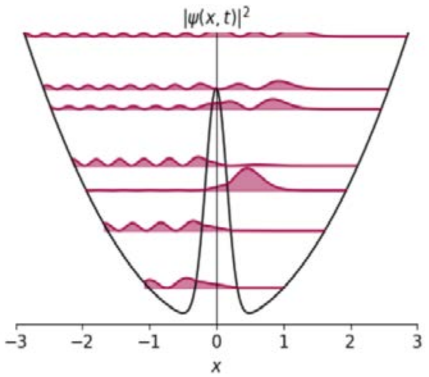

Fig.1:Probability density of lowest electron states in a harmonic gaussian potential with an applied electric field.

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Spin-selective light-matter coupling of a 2D hole gas-microcavity system in the Quantum Hall regime

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We present an experimental demonstration of spin selectivity in the strong coupling between the electromagnetic mode of a semiconductor microcavity and an electronic transition in a hole-doped GaAs quantum well. To achieve this, we exploit the exotic properties of a 2D hole gas confined to a quantum well when operating in the quantum Hall regime [1]. For a high charge density, we demonstrate how the manipulation of the filling factor ν (defined as the ratio between the charge density ρ and the density of states n_B) through an external magnetic field B, leads to an imbalance in the population of each spin band, which in turn manifests as a selective strong coupling (Fig. 1) that can be probed through the circular degree of polarization of the exciting light.

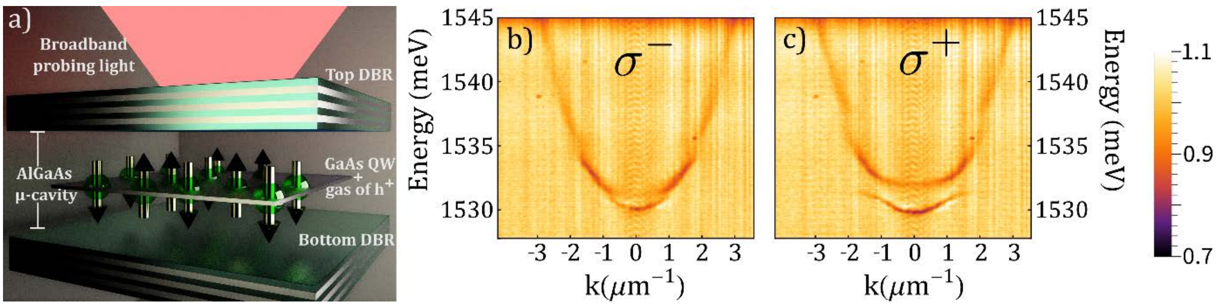

Fig. 1: a) Schematic representation of the physical system. A quantum well embedded in a semiconductor microcavity hosts a 2D gas of holes. When operating in the quantum Hall regime, for the condition $2 > \nu > 1$, the system reaches the spin-selective light-matter strong coupling. As displayed in panels b and c, the population with σ^- spin (b) does not couple to the cavity mode, while σ^+ operates in the strong coupling regime, as benchmarked by the observable lower and upper polaritonic branches in the reflectivity contrast (c).

The effect originates in the modification of the density of states for each Landau level induced by B. At 0T, and for a fixed high charge density, both Landau levels (σ^- and σ^+) are full, inhibiting any electronic transition to the Landau levels in the conduction band. Upon increasing B, the density of states is modified, but the Zeeman splitting generates the condition where σ^+ has available states (and hence an optically induced electronic transition is possible) but σ^- is still full. Our measurements are collected in a confocal setup of high numerical aperture, which allows to map the energy dispersion of the system, as shown in Fig.1 b-c.

This demonstration opens perspectives for the manipulation of the non-linearity in polaritonic systems through the circular degree of polarization of the light. Each polarization would experience a completely different value of the $\chi^{(3)}$ nonlinearity, which originates from the excitonic component of the polaritonic quasi-particle.

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Next nearest neighbour coupling in exciton-polariton condensates

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Driven-dissipative Bose-Einstein condensates of exciton-polaritons in planar microcavities have substantially advanced in reconfigurable optical lattices and hence became a promising tool to engineer and explore phases of matter in extreme settings and to simulate complex Hamiltonians. Conventionally nearest-neighbour (NN) coupling dominates over next-nearest-neighbour (NNN) coupling in this system making polariton networks inherently planar in a graph topology sense. In this study [1] we experimentally demonstrate that the next-nearest-neighbour coupling can be made stronger than nearest-neighbour coupling in ballistically expanding spin-orbit coupled exciton-polariton condensates. We realise the screening of the NN coupling by exploiting the dependence of the interaction strength between polaritons on the relative orientation of their pseudospins, which was recently proposed theoretically [2]. We utilize spin-orbit coupling induced rotation of the pseudospin occurring while polaritons propagate from the condensate to its neighbours in a chain of three coupled condensates, see schematic in Fig.1. Spin-screening of the condensate coupling depends on the ratio between their relative separation distance (denoted d) and spatial precession period of the condensate pseudospin (denoted ξ). When NNs are separated by $d = (n-1/2)\xi$, where $n=1,2,3\ldots$, polaritons arrive at their NNs with the opposite spin-projection [see Fig.1(a)], which reduces the NN condensate coupling while the next-nearest neighbours are still interacting strongly. This effect was evidenced in both relative intensity of the spin-screened condensate [see Fig.1(a)] and in threshold dependence for the whole system [see Fig.1(b)].

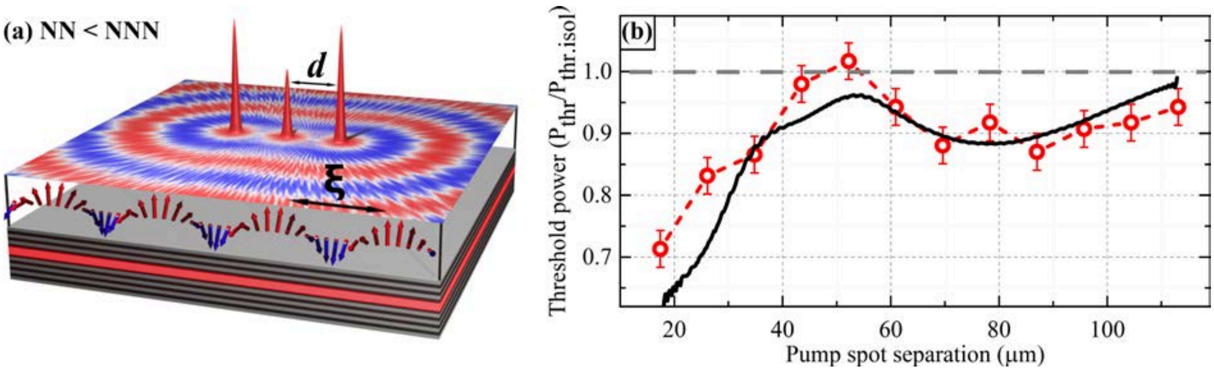

Fig. 1: (a) Schematic representing pump geometry where the distance between the central and edge pump spots equals to the half pseudospin oscillation period (NN is weaker than NNN). The height of the peaks represents the intensity of the condensate emission, and the red, white, and blue colour map shows the precession of the polariton pseudospin propagating in the cavity plane, with red representing S_z=+1 (spin-up polaritons) and blue representing S_z=-1 (spin-down polaritons). Red and blue arrows show the pseudospin precession of the polaritons propagating from the edge condensates along the triad axis. (b) The system threshold power dependence on the separation distance between the condensates pump spots measured experimentally (red circles) and calculated numerically (solid black curve).

We believe that demonstrated in our study alteration of the conventional condensate coupling hierarchy may open a new horizon for both the theoretical and experimental investigation of the physics and applications of polariton simulators as the platform for addressing NP-problems.

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Observation of a single quantized vortex vanishment in exciton-polariton superfluids

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We report the direct observation of a single quantized vortex vanishing from a microcavity exciton-polariton superfluid. Exciton-polariton vortices generated by a non-resonant Laguerre-Gaussian optical pumping beam reveal themselves in the energy-integrated emission image, representing a multimode entity consisting of the ground- and excited states. From the time-resolved spectroscopy measurements utilizing various Laguerre-Gaussian beam sizes, we find that the two lowest-energy states get populated and compete with each other, manifested by the change in their mutual population with the beam diameter. Furthermore, we study the transition from the excited state characterized by the finite orbital angular momentum (and a vortex in the direct space) to the ground state under pulsed excitation conditions. Our experimental findings are in excellent agreement with the numerical calculations employing the driven-dissipative Gross-Pitaevskii equation coupled with pumping reservoirs. Thus, our study provides an experimental and theoretical platform to investigate nonequilibrium vortex dynamics and manipulate multistate polariton condensates in semiconductor microcavities.

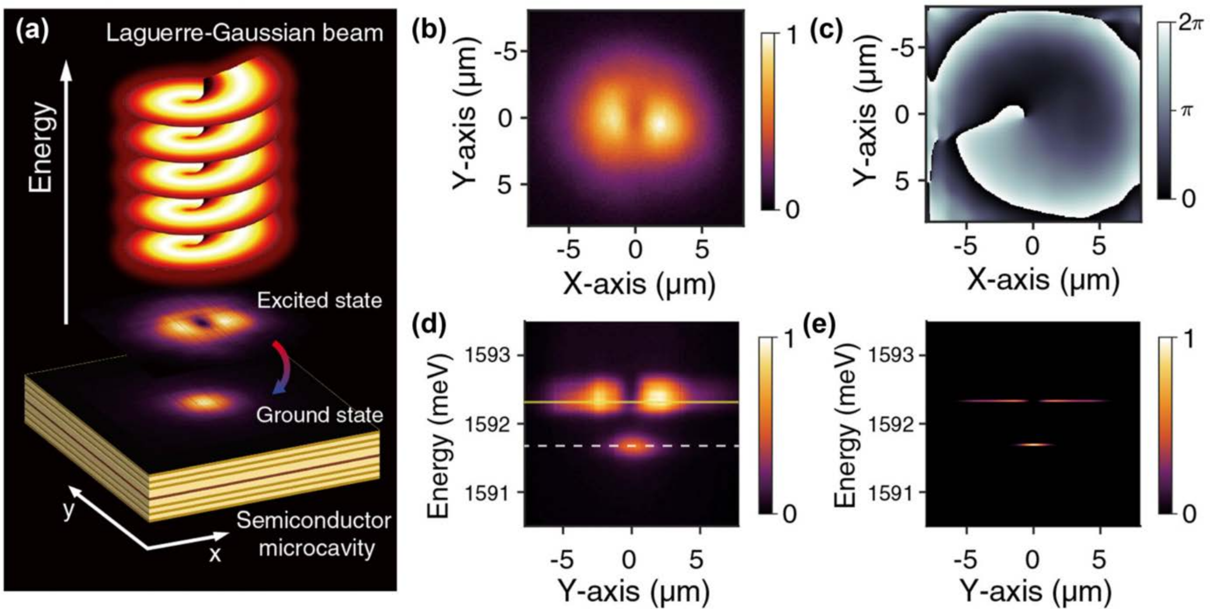

Fig. 1: (a) Schematic illustration of experiment. Semiconductor microcavity is excited by nonresonant LG beam with OAM |l| = 1. Above the pumping threshold, polariton condensates are formed in two different energy states with different density distribution. (b) Energy-integrated PL image of the condensates above the threshold density. (c) Phase map of (b) shows 2π phase winding. (d) Real-space spectrum along line x = 0 in (b). (e) Calculated real-space spectrum of the condensate.

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Collective excitations of high-density optically trapped exciton-polariton condensates

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Collective excitations of a bosonic condensate underpin its hydrodynamic and thermodynamic properties. In conservative systems, like ultracold atomic condensates, experiments cleanly agree with the Bogoliubov theory of excitations. However, an extension of the Bogoliubov theory to non-equilibrium systems, like exciton-polariton condensates, is not straightforward. This issue is exacerbated by the coexistence and interaction of the condensate with an incoherent reservoir of excitons.

In this talk, I will present a series of experiments probing the excitation spectrum of large optically trapped condensates in a high-quality optical microcavity with embedded GaAs quantum wells. Interaction-dominated high-density condensates are formed in these traps with relatively homogeneous distribution near the center [1], enabling clean measurements of the excitation spectra.

Steady-state and polarization-resolved measurements allow us to directly measure the excitation spectrum of a spinor condensate and extract the spin-dependent interaction constants for polaritons in GaAs-based systems [2]. Pulsed excitation experiments lead to long-lived collective oscillations of the condensates that enable a measurement of the speed of sound [3]. Discrepancy with the Bogoliubov theory suggests a strong influence of the incoherent reservoir. Finally, we extract the Bogoliubov amplitudes in a wide range of momenta and show that they agree with a generalized version of Bogoliubov theory [4]. The theory takes into account the strong role of uncondensed particles composed of the excitonic reservoir and the optically dark superposition of excitons in an optical microcavity with multiple exciton-hosting quantum wells. Our results represent a significant step towards understanding the fundamental properties of non-equilibrium polariton quantum fluids.

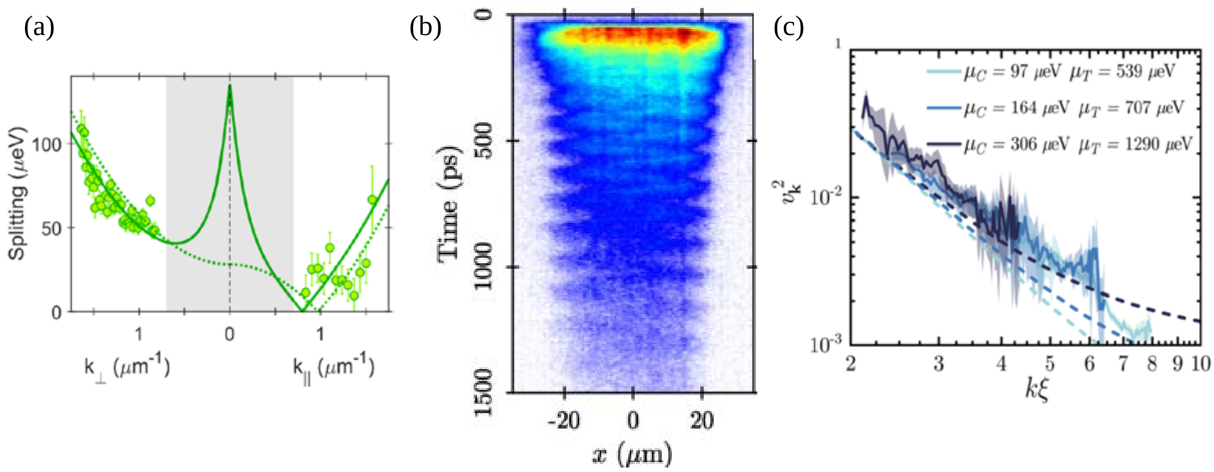

Fig. 1: (a) Excitation energy splitting with theoretical fits (solid lines) for a spinor polariton condensate [2]. (b) Long-live condensate oscillation in the pulsed excitation regime [3]. (c) Bogoliubov amplitudes for different condensate densities with theoretical predictions (dashed lines) [4].

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Electric and magnetic field effects in vertically coupled conical quantum dots

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Starting from a structure composed by two vertically coupled conical quantum dots (CQDs) of GaAs surrounded by $Al_xGa_{1-x}As$ at a concentration of x = 0.3, the effects of applied electric and magnetic fields on the eigen-energies and eigen-functions are evaluated by varying the principal quantum number (l = -1, 0, 1). In addition, the effects are evaluated by including the presence of a shallow-donor impurity, located in the lower quantum dot. Using the finite element method, variations in the energies and wave functions of the system are evidenced. By analyzing the behavior of the binding energy, the effects of photoionization are studied. Finally, the presence of the impurity in the system generates an additional potential, consequently, the energies in the structure decrease under the evaluated effects, making more forceful changes in the wave functions and energies due to this potential.

Keywords: Conical quantum dots, electric field, magnetic field, shallow-donor impurity, binding energy, photoionization cross section.

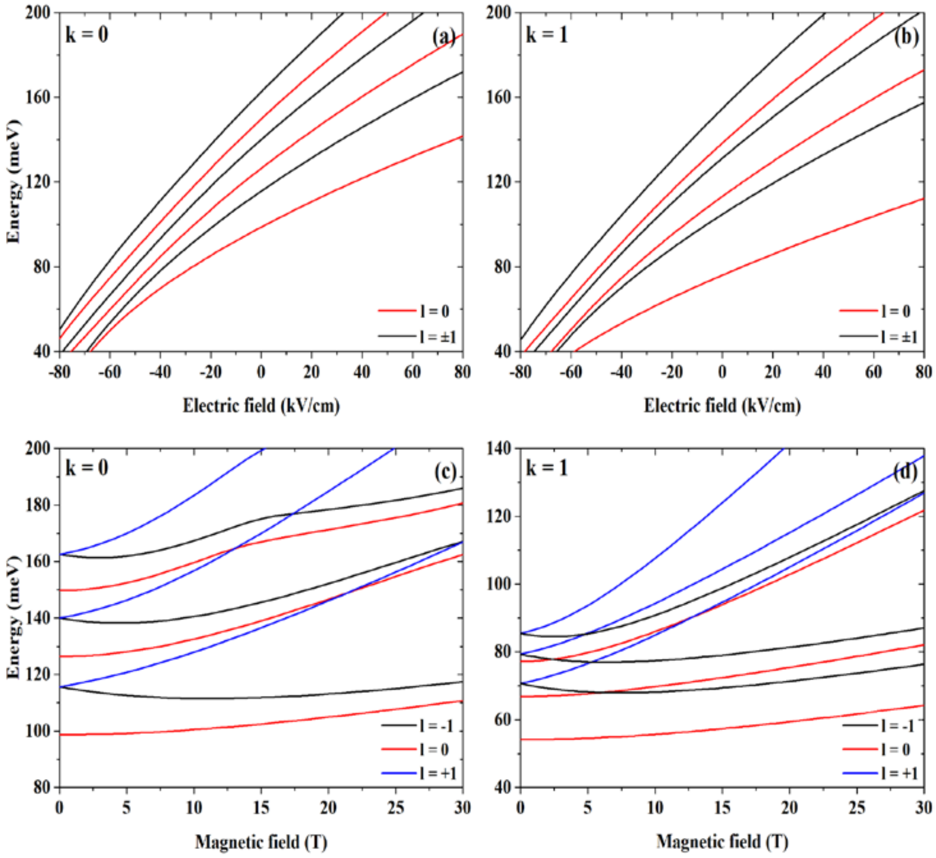

Fig. 1: Energy of the lowest confined electron states under the electric field effect without/with donor impurity (a)/(b). In panels (c)/(d) the results are as a function of the applied magnetic field.

A survey of Photocatalytic effect of ZnO/SnO_2 over methylene blue samples

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Compounds formed by oxygen and metals (SnO2, CuO, ZnO, NiO, Co3O4, TiO2) are known as metal oxides, which have a lot of physical-chemical properties, one of them mainly as semiconductor in basal conditions. Metal oxide semiconductors (MOSs) has been studied along because of application versatility. MOSs have been taking relevance and interest to be synthesized as nanoparticles improving their properties by means of a variety of methodologies and techniques according to needs of application, photocatalytic, energy, environmental, biomedical, etc [1]. These materials have been used usually in environmental remediation by its catalyst property against different colorants used in textile industry, as it is methylene blue case, which generate millions of liters of waste water per year around the whole world [2]. In this work we carried out an experiment with SiO_2 substrates with SnO2 and ZnO thin films deposited by means of spin coating technique, materials were put in on contact (behind and in front) over solutions with different methylene blue concentrations (2 ppm, 4, ppm, 6 ppm, 8, ppm and 10 ppm), all of them irradiated with UVA, UVB and both combined lights for several hours. We have been found results reducting absorbances after UV light cross the material and substances or vice versa. Mayor absorbance reduction has been observed with lower concentrations and when materials is placed behind samples.

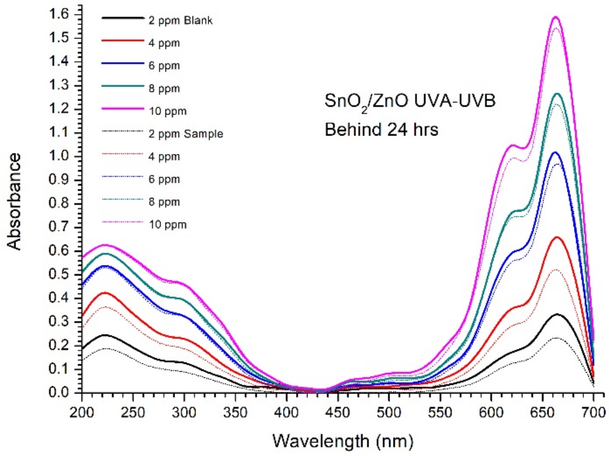

Fig. 1: Methylene blue samples (2 pm, 4 ppm, 6ppm, 8 ppm and 10 ppm) irradiated with UVA-UBV light for several hours and absorbance UV-VIS spectrum from 200 to 700 nm, showing an increasing after light contact in all cases.

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Optical properties in a conical-shape core/shell quantum dot with a wetting layer: Effects of an electric field and temperature

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Numerically we study the nonlinear optical properties of a conical-shaped core/shell quantum dot, considering the combined effects of a wetting layer, an applied electric field, and core/shell geometric parameters. Within the framework of the effective mass approximation and using the finite element method, the intraband transitions lifetime of the carriers as well as, the linear, nonlinear, and total absorption coefficients are determined. The results show that a red or blue shift can be achieved depending on the choice of the appropriate parameters, in addition that the application of an electric field increases the absorption coefficient and that the transitions lifetime of the carriers decreased as the temperature increased.

Electronic structure and absorption coefficient for 2D GaAs doped with Si, Ge and Sn amphoteric impurities: A DFT study

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Two-dimensional systems are a field with a lot of activity in the two last decades, although these were theoretically reported by P.R. Wallace since 1947 [1], the graphene mechanical exfoliation performed by Andre Geim and Konstantin Novoselov in 2004 gave them the Nobel Prize in 2010 "for groundbreaking experiments regarding the two-dimensional material graphene" [2]. Without a doubt, the impact of the discovery of 2D systems such as graphene encourage to both theoretical and experimental investigations of many other materials such as silicene, borophene, arsenene, phosphorene, just to mention some of the most emblematic ones. Following this research area, in this work we present results of the imaginary part of the dielectric function, as well as the absorption coefficient, for the pristine 2D GaAs system and with amphoteric substitutional impurities like silicon (Si), tin (Sn) and germanium (Ge), that means that depending on which atom is substituted, this can act as a *n*-type or *p*-type impurity on the system. We found that the levels do indeed appear near the conduction band (or valence) if the impurity is *n*-type (or *p*-type) for Si and Ge atoms, not the case of Sn atoms, that report that an energy level for *n*-type impurities is located at the Fermi level, as can be seen in figure 1, and the *p*-type one is close to the valence band maximum. The absorption coefficient for the system has a part in the visible region on the electromagnetic spectrum, that is slightly modified by the impurities.

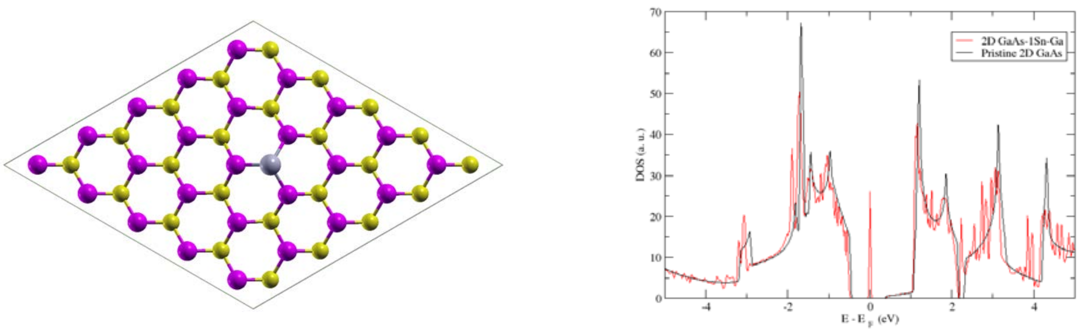

Fig. 1: Unit cell for a 2D GaAs doped with a tin (Sn) atom in a gallium (Ga) position (1Sn-Ga), and the computed density of states for the pristine 2D GaAs (black-lines) and the one for the 2D GaAs-1Sn-Ga system.

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Acknowledgements
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Tunable photonic band gaps in two-dimensional Bravais-Moiré photonic crystal composed of copper oxide high-temperature superconductors

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We perform a theoretical study of light propagation properties in two-dimensional square photonic crystals (PCs) following Bravais-Moiré (BM) patterns composed of copper oxide high-temperature superconductors (HTSCs). The BM PCs are made of cylindrical cores formed from the combination of two square Bravais lattices [1]. The Moiré pattern forms due to a commensurable rotation of one of these lattices with respect to the other. The dielectric function of the superconducting material is modeled by the two-fluid Gorter–Casimir theory [2]. We report on the corresponding gap mapping as a function of the radius of dielectric cores as well as the dispersion relations of TM modes for BM PCs and for the waveguide system built of defect lines within such crystal. BM PCs composed of copper oxide HTSCs exhibit large tunability by temperature and magnetic fields.

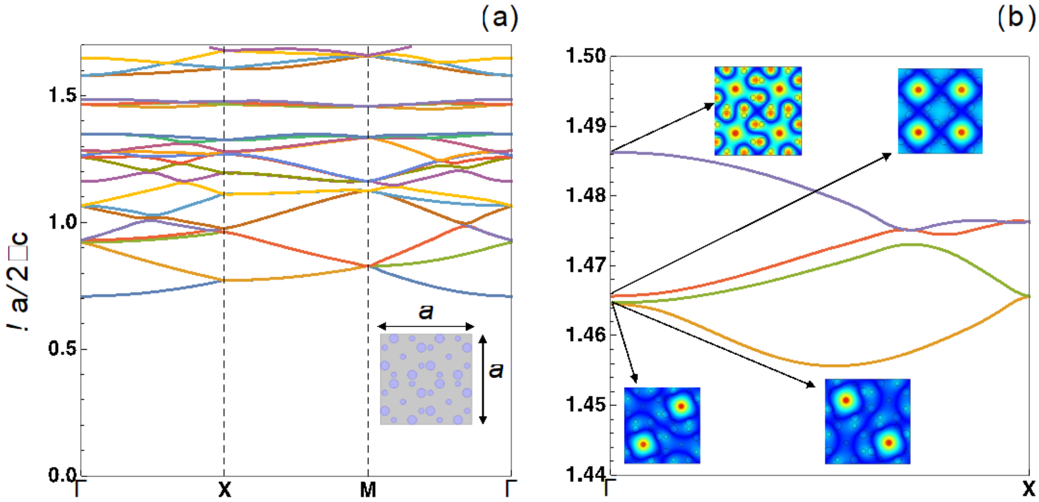

Fig. 1: (a) Dispersion relation for TM modes of BM PCs composed of cores of copper oxide HTSCs in a background of air at T = 15 [K]. (b) Zooming of dispersion relation in (a) around normalized frequencies $1.44 < \omega a/2\pi c < 1.50$ with fields profile at Γ point of four modes in this region.

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Unconventional Polariton in Van der Waals Semiconductors

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Many van der Waals semiconductors feature large oscillator strengths and therefore robust polariton modes. At the same time, they allow the flexibility to construct heterostructure and to integrate with a variety of substrates. They therefore open the opportunity to create polaritons with unconventional exciton properties, photon properties and new degrees of freedom. We will discuss a few different types of 2D material polariton systems that may potentially enable novel many-body phenomena and polariton technologies.

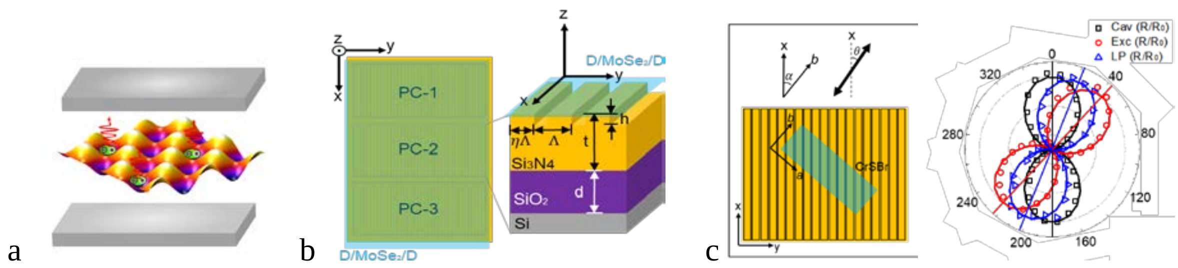

Fig. 1 Different types of 2D material polariton systems. (a) Moiré exciton-polaritons with quantum confinement-enhanced nonlinearity. (b) Large-area monolayer coupled with photonic-crystal cavity arrays. (c) Anisotropic exciton-polaritons with magnetic field tunability.

Quantized Vortex Formation in the "Rotating Bucket" Experiment with Nonlinear Fluids of Light

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Polaritons are quasi-particles that arise in the strong coupling regime between matter excitons and cavity photons in the semiconductor microcavity. Being the composite bosons, under certain conditions they can occupy single energy-momentum state forming non-equilibrium Bose condensate. Polariton condensates are shown to be a superfluid and can possess quantized vortices [1]. Numerous ways of vortex generation and topological charge control had been discovered already [2]. However, vortex formation in the so-called "Rotating bucket" experiment, when the reservoir with the superfluid [3] or atomic condensates [4] is stirred mechanically, has remained illusive. Here, for the first time, we realize the "rotating bucket" experiment with polariton condensates [5]. We create the rotating trap for polaritons by virtue of the beating note of two stabilized non-resonant continuous-wave lasers. Each of the excitation beams is shaped into the annulus with the opposite optical angular momenta *l* (OAM) of +1 and -1, respectively. The resultant beating note of the lasers has a dumbbell shape and rotates with the frequency f´ dictated by the lasers OAM and frequency detuning exerting effective torque to polariton condensate. The short polariton lifetime shifts the critical frequency of the vortex appearance to the GHz range compared to the few Hz for superfluid He. At f´= 2 GHz, the condensate occupies the first excited state of the rotating potential and has a donut shape (see fig.1 (a)). Retrieving the phase of the condensate wavefunction by interferometric means, we observe a clear vortex corotating with the stirring direction (see Fig.1 (b)). Similar to the superfluids in the "rotating bucket" experiment, the rotated polariton condensate sustains one vortex in the narrow range of stirring frequencies from 1 to 4 GHz (see Fig.1 (c)) [5]. We also study the polariton system numerically and reproduce the experimental results with 2D Gross-Pitaevskii equation. Our findings open new perspectives for the comparative studies of polariton condensate on par with the other superfluids, as well as offer a new generation technique of the vortices with the definite topological charge. This can be applied for the analog simulations and offers the possibility for investigation of polariton condensates in the time-periodic potentials.

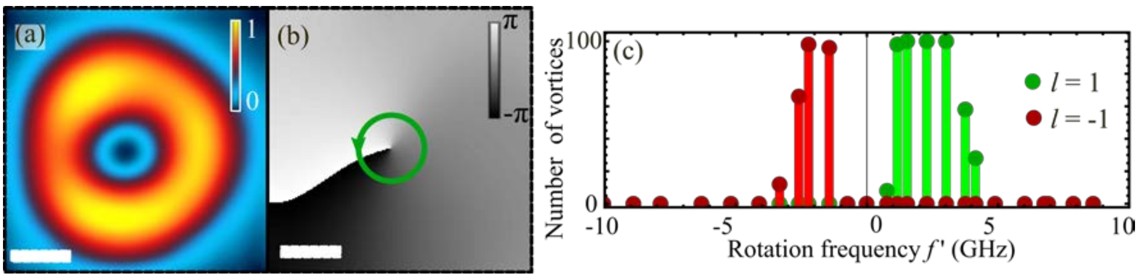

Fig. 1: (a) Intensity and (b) phase distribution of the polariton condensate in the rotating (at 2 GHz) optical trap. The white scale bar corresponds to 2 µm. (c) Rotation frequency dependence of the vortex appearance, depicting the number of experimental condensate realizations with vortex out of 100. The red color corresponds to l = -1, and green to l = 1 respectively.

This work was supported by the Russian Science Foundation (RSF) grant № 21-72-00088, https://rscf.ru/project/21-72-00088/

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Light-matter coupling in CrI_3 magnetic monolayers

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Chromium trihalides (CrI3, CrBr3 and CrCl3) is a family of 2D materials which combine the presence of ferromagnetic ordering of the Ising type with robust excitonic response up to room temperature.

The interaction between excitons and magnetic lattice of these materials can lead to a set of remarkable optomagnetic effects, which include polarization-sensitive resonant magnetization switching and excitonic anomalous Hall effect.

Moreover, huge binding energies (up to 1 eV) and optical oscillator strengths of bright excitons in CrI_3 make this material an attractive candidate for polaritonics, with characteristic Rabi splitting of several tens of meV. The presence of lattice ferromagnetism also leads to record-high values of polariton Zeeman splitting up to 15 meV, which can be of importance for spinoptronic applications.

In our talk we will present the theory of aforementioned effects.

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Composed effects of electron-hole exchange and near-field interaction in quantum-dot-confined radiative dipoles

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At present, semiconductor quantum dots (QDs) are of great interest for the advance of different optoelectronic technologies, including emitters for photon-based quantum information processing [1-3]. However, the optimization of such devices toward massive use, requires comprehensive understanding of the optical response of single emitters under different influences such as the optical Stark effect, electric/magnetic fields, asymmetric stress fields, and non-negligible electron-hole exchange [4,5]. Additionally, if neighboring dots are close enough, resonant tunneling and Förster energy transfer may play a substantial role on the photon-emission dynamics.
In particular, the electron-hole (E-H) exchange and the Förster energy transfer (FET), both mainly modeled in terms of dipole-dipole interactions, are phenomena that exhibit similar spatial ranges and comparable energy scales, in despite of the interdot character of the former as compared to the intradot character of the latter (which depends strongly on the E-H overlap) [6,7].
In this work, we study the spin dynamics of an optically-generated bright exciton confined in a quantum dot under both intra and interdot decoherence. On the one hand, the radiative dipole is subject to E-H exchange, and on the other hand, it is exposed to the FET interaction due to the near presence of a second dot, as shown in figure 1.
By means of numerically solving the corresponding Lindblad master equation, we simulate the interplay of these two perturbing processes on the time dependent polarization of the exciton spin. The computational results suggest that under particular conditions, the composed effect of both decoherence channels, may favor preservation of the spin direction, which represents a very convenient scenario for the extended use of quantum dots as reliable on-demand sources of polarized photons.

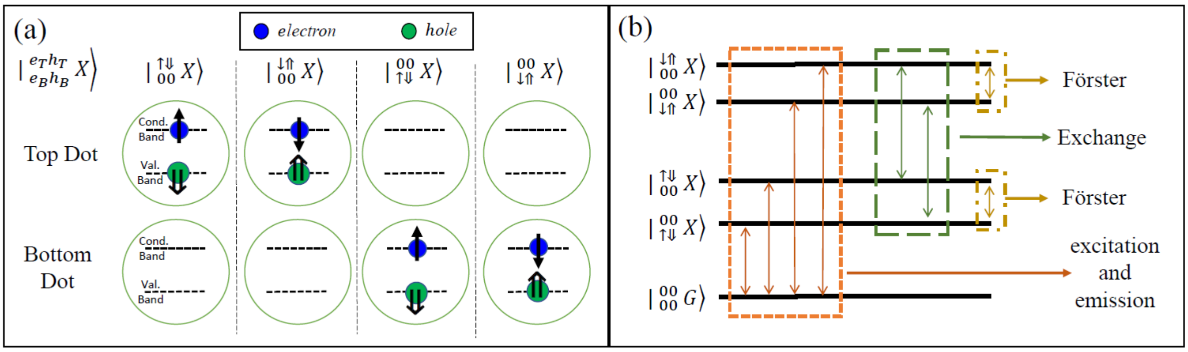

Fig. 1: (a) Representation of the four considered spin-defined exciton states. (b) Coupled states by pumping and emission, and the studied interactions: E-H exchange (intradot) and FER (interdot).

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Magneto-Optical Chirality in a Coherently Coupled Exciton–Plasmon System

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Chirality is a fundamental asymmetry phenomenon, with chiral optical elements exhibiting asymmetric response in reflection or absorption of circularly polarized light. Recent realizations of such elements include nanoplasmonic systems with broken-mirror symmetry and polarization-contrasting optical absorption known as circular dichroism. An alternative route to circular dichroism is provided by spin-valley polarized excitons in atomically thin semiconductors. In the presence of magnetic fields, they exhibit an imbalanced coupling to circularly polarized photons and thus circular dichroism.

In this work we present a metasurface based on a WSe_2 monolayer and an array of gold (Au) nanodisks. We demonstrate the transfer of polarization-contrasting optical transitions associated with excitons in the WSe_2 monolayer to proximal plasmonic nanodisks by coherent coupling. The coupled exciton–plasmon system exhibits magneto-induced circular dichroism in a spectrally narrow reflectivity window in an otherwise broad-band opaque medium. We elucidate this effect of Fano interference in the weak-coupling regime as a function of exciton–plasmon spectral resonance detuning and study both experimentally and theoretically the polarization properties of the coherently coupled system in the presence of external magnetic fields [1].

Our work motivates the use of exciton–plasmon interfaces as building blocks of chiral metasurfaces for applications in information processing, nonlinear optics, and sensing.

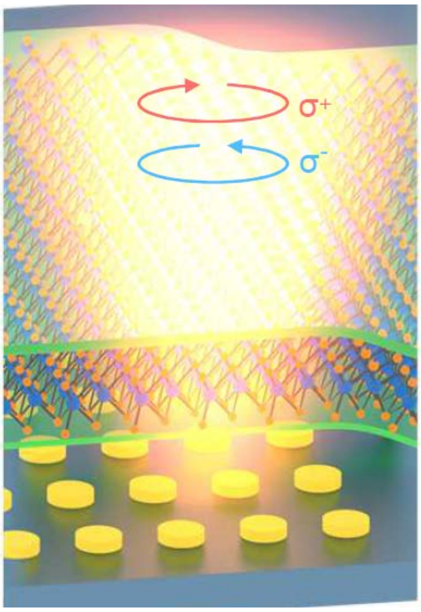

Fig. 1: Experiment schematics: WSe_2 monolayer encapsulated in hBN and placed on Au-nanodiscs is studied in polarization dependent optical reflection.

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Self-consistent study of GaAs/AlGaAs quantum wells with modulated doping

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For the implementation of a device for some practical application either in electronics, optoelectronics, etc. It is essential to include the effect of donor density as this increases the transport properties and therefore amplifies the response of the System. In this sense, in this work a GaAs quantum well system with AlGaAs barriers has been studied, analyzing the energy spectrum, the electron density, the Fermi level considering geometric modifications such as the well width and the inclusion of a doped delta layer in symmetric and non-symmetric positions, and non-geometric modifications such as the donor density in the System. Finally, a study of electromagnetic induced transparency (EIT) has been carried out as a possible application of this system in optoelectronics.

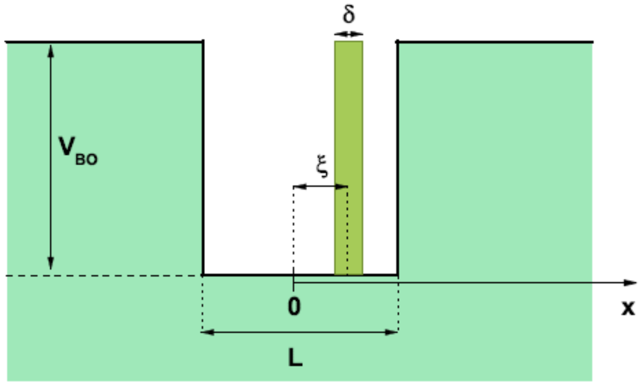

FIG. 1: System schematic corresponding to a quantum well of height V_0 and width L centered at the x axis origin. The doped delta layer of width δ located at a distance ξ from the coordinates origin is shown in green.

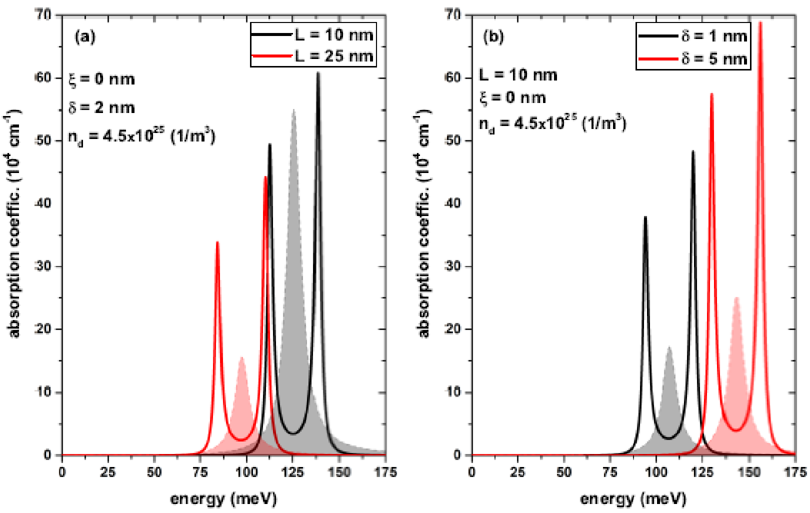

Fig. 2: Electromagnetic induced transparency and absorption for a GaAs/AlGaAs quantum well including a doped delta layer in the center of the well. (a) System with the delta layer of width 2 nm and two well widths of 10 nm and 25 nm (black and red curve respectively). (b) System with a fixed well width of 10 nm and varying the width of the delta layer from 1 nm to 5 nm (black and red curves respectively).

Optical properties of impurities in GaAs spherical quantum dots under the Kratzer potential

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The optical and electronic properties of quantum dots depend on geometric or stoichiometric factors, as well as on external factors such as the effects of electromagnetic fields. However, this is a topic that deserves attention because of the particular form of potential energy that can consider important physical facts when a shallow donor impurity is taken into consideration. This combination with factors allows to investigate new possible behaviors for the optical properties of interest. In this work, we consider a spherical quantum dot with a GaAs/AlGaAs core/shell structure with its Kratzer-like energy potential profile, which, depending on the chosen parameters. We calculate the corresponding electronic structure by working within the effective mass approximation and solving the Schrödinger equation of one electron by a finite element method (FEM). The results of the absorption coefficients for the system are shown as a function of the geometric parameters and the variables of the Kratzer-type confinement potential. For a fixed configuration of these quantities we investigate the effect of an applied electric field along the z-direction, as well as a constant magnetic field in the same direction, but not applied simultaneously. Here we can conclude that the parameter of the Kratzer-type confinement potential allows us to adjust the optical properties associated with the binding energies when the impurity is present or not, as well as the electric and magnetic fields that induce a peaks displacement and a variation of the amplitude of the optical response [1,2].

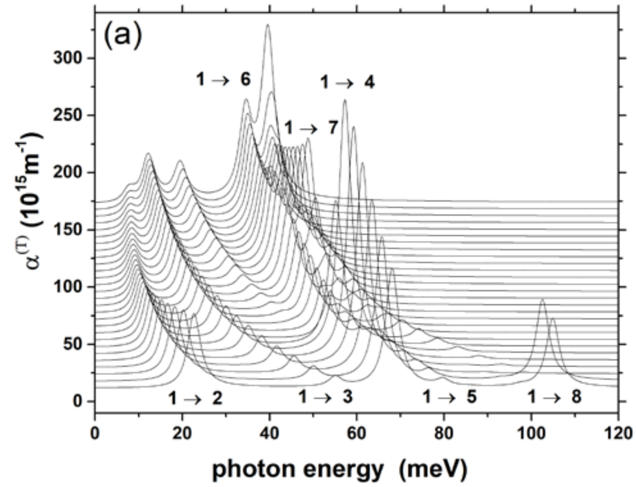

Fig. 1: Nonlinear optical coefficients in function of the photon energy for different values of the geometrical Kratzer potential parameter**.**

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Influence of a non-resonant intense laser and topological defect on the electronic properties of a GaAs quantum ring under inversely quadratic potential

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In the framework of the effective mass approximation, the effects of a non-resonant intense laser and a topological defect on the electronic properties of an electron confined in a simple GaAs quantum ring are investigated. The energies and wave functions of the system are determined by solving the Schrödinger equation using the finite element numerical technique including a topological defect in the geometry of the system. The inclusion of a non-resonant laser is used to model changes in the confinement potential, whereby this effect generates significant changes in the energy spectra.

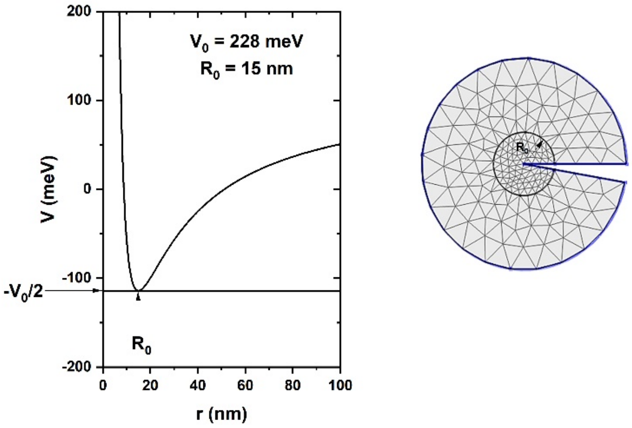

Fig. 1: The figure on the left is a diagram of the inversely quadratic potential, whose potential minimum is found at $r = R_0$ with a value of energy $-V_0/2$. On the right the geometry of the structure with a topological defect of 10° is shown, the blue lines correspond to the boundary conditions for the problem.

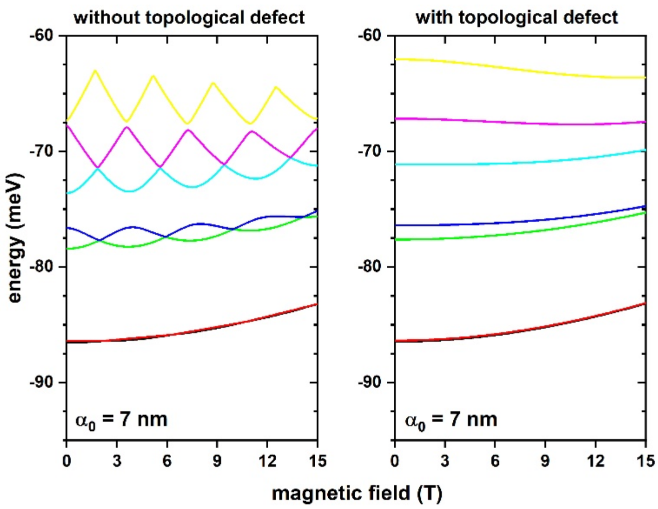

Fig. 2: Electron energy levels confined in a GaAs quantum ring under the inversely quadratic potential, with intense non-resonant laser and topological defect.

DFT studies of the borophene basic optoelectronic properties doped with aluminum and gallium substitutional atoms

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Currently, two-dimensional materials are widely studied from both theoretical and experimental points of view. Among the large list of possible two-dimensional systems, we can find a two-dimensional boron (borophene) allotrope, which has attracted considerable attention due to its promising electronic and optical properties. Understanding and modifying these properties are crucial for implementation of borophene in high-technological applications, but for this to be possible we need to know its very basic physical properties. Therefore, in this work we study borophene employing *ab initio* techniques to examine the variation of the optoelectronic properties of a pristine borophene monolayer, and the one with Al and Ga substitutional impurities. All this task using SIESTA code (acronym for "Spanish Initiative for Electronic Simulations with Thousands of Atoms"), which is a method and a computer program for electronic structure calculations. We report the band structure with the correspondingly density of the states for the pristine system as well as for the doped borophene one. We do reproduce the optical conductivity for the pristine borophene considering several values of the scattering time parameter (τ) of the Drude's model [1], obtained from the imaginary part of the dielectric function depicted in figure 1. We report in this paper the effect of the impurities on the optical conductivity with the same set of τ parameters as well as the absorption coefficient with *x*- and *y*-polarized incident light. We found that the impurities significantly modify the optical conductivity, but most importantly it that this enhances the absorption coefficient in the visible region of the electromagnetic spectrum.

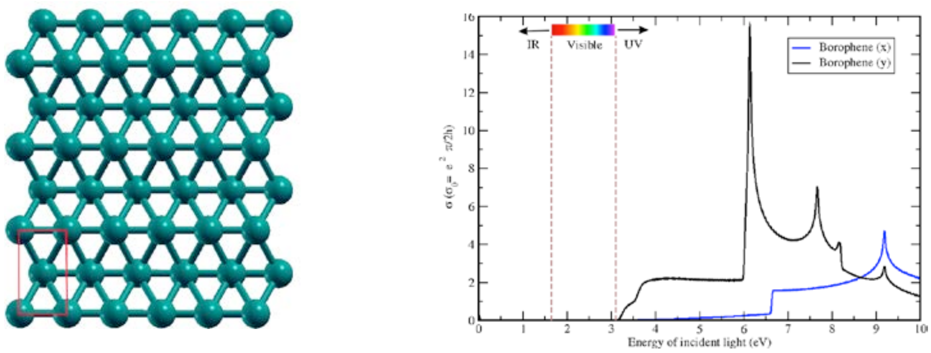

Fig. 1: Pristine borophene structure with the unit cell depicted, and the computed optical conductivity, that coincides with those reported in [1], with light polarized in x- and y-directions.

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Acknowledgements

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Energy spectrum of an exciton in a type II core/shell quantum dot. Effects of intense non-resonant laser radiation

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Using the effective mass approximation in a two-band parabolic model and applying the finite element method, we carried out a theoretical analysis of the effects of an intense non-resonant laser radiation and the variation of geometric parameters on the energy spectrum of an electron, a hole, and an exciton confined in a CdTe/CdSe core/shell truncated conical quantum dot. The solution of the Schrödinger equation allows to analyze the charge distribution inside and outside of the nanocone in the presence of the laser radiation and the variation of the structure´s geometric parameters and to calculate the absorption coefficients, the coefficient of the relative change of the refractive index as well as, the electromagnetically induced optical transparency. The results reveal interesting optical properties based on the size quantum effect in type II conical semiconductors, which may be important for a wide range of applications in semiconductor nanostructures.

Spin Orbit interaction and Zeeman effect contributions to electro-optical properties in a double quantum ring

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The possibility of controlling the optoelectronic properties of low-dimensional systems allows establishing potential applications in electronic devices. The spectra of this class of systems undergo strong changes due to effects of geometry, size, electric and magnetic fields, intense non-resonant laser, among others [1].

When a magnetic field is applied to a system, the spin-orbit interaction (SOI) and the Zeeman effect generate changes in its behavior, which must be considered for a better understanding.

In Fig. 1, the geometry is shown, and the depicted vectors represent magnetic field in z-direction and nonresonant field for linear and circular polarizations. In this work, a double ring with azimuthal symmetry is studied, whose profile of the transversal section was taken from the work [2]. The model includes a magnetic field and an intense non-resonant laser with both linear and circular polarization, taking into account the SOI and Zeeman effect. The influence on the spectrum of these external quantities were studied, as well as the absorption of the system to a laser signal with right and left circular polarizations.

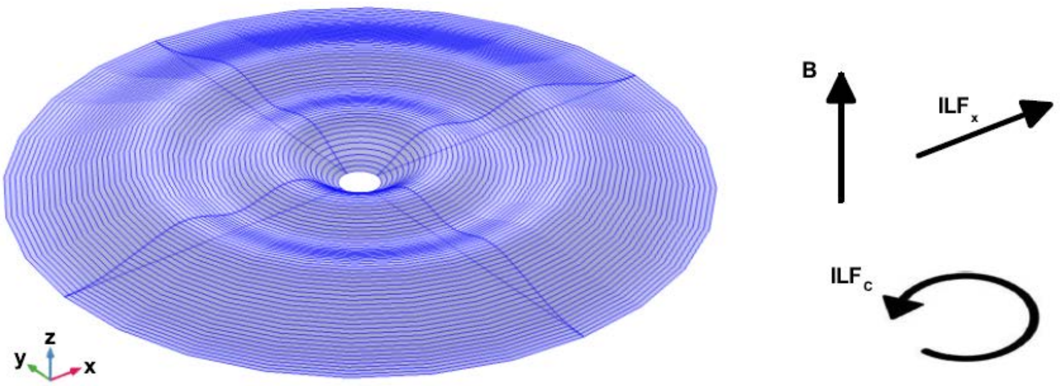

Fig. 1: Representation of a double GaAs/AlGaAs Quantum Ring

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Effects of quantum confinement in Ag nanoparticles on the spectroscopic properties of the Pr^{3+} ion doped in germanate glass

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In this work we present the plasmonic effects of Ag nanoparticles on the spectroscopic properties of the Pr^{3+} doped ion in a GeO_2-PbO glass. The Ag nanoparticles were obtained via ion implantation with an energy of 450 KeV and a dose of 1*10 ion/cm^2. The synthesis of GeO_2-PbO glass doped with Pr^{3+} was made by the conventional melt-quenching method. The presence of Ag nanoparticles was demonstrated through the resonant surface plasmon observed using UV-VIS spectroscopy and transmission electron microscopy. A simulation of the electromagnetic coupling between plasmonic resonances generated by the Ag nanoparticles and the Pr^{3+} ions was performed using a quantum approach, justifiable by the small size of the nanoparticles [1, 2]. Changes in the emission wavelengths of the Pr^{3+} ion under excitation of 488 nm were observed, presumably due to the presence of Ag nanoparticles and changes in the Stark energy levels, which leads to modifications in the selection rules. The results obtained show that there is a strong quantum coupling between the Pr^{3+} ion and the Ag nanoparticles which allows us to understand the plasmonic effects in the synergy between this rare earth ion and the nanoparticles.

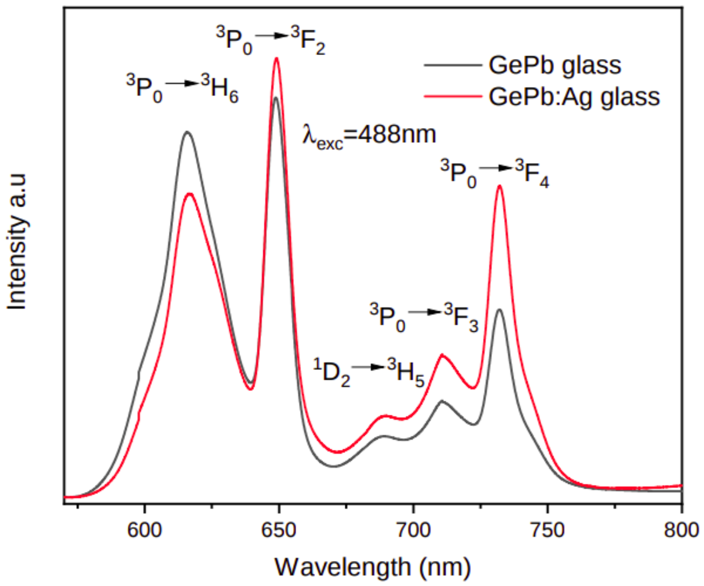

Fig. 1: Spectroscopic emission of Pr^{3+} doped GeO_2-PbO glass with (red line) and without (black line) Ag nanoparticles

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Catechol aromatic molecular system used as a spintronic device

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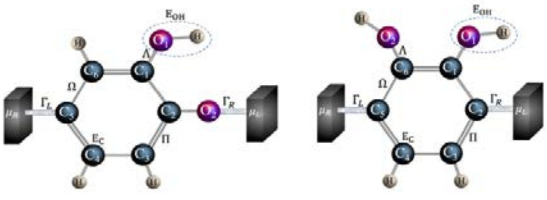
Recently, the study of molecular nanoelectronic devices has generated great interest, especially for their use as functional junctions of molecular wires, such is the case of the singular Catechol molecule. Due to its special application, in this work we study the spin-dependent electron transport through such a molecular system coupled to two semi-infinite contacts, as shown in the figure:



(a) **(b)**

We model this system considering different geometrical configurations (see figures (a) and (b)), characterized by a tight-binding Hamiltonian, $H = H_C + H_L + H_I$, where H_C, H_L and H_I, correspond to the Hamiltonian of system without contacts, to the contacts and the interaction of the system with the contacts, respectively, in the framework of Green's functions under a real-space renormalization scheme through the Dyson equation given by $G = G^0 + G^0(\Xi_L + \Xi_R)G$, where G^0 is the off-contact Green's function and Ξ_L and Ξ_R are the self-energies of the left and right leads, respectively.

The linear conductance can be obtained from Landauer's formula at zero temperature $\mathcal{G}_\sigma = (e^2/h)T_\sigma(\omega = \varepsilon_F)$ where $T_\sigma(\omega)$ is the transmission probability for the spin state σ [1].

We introduce the spin polarization as $P_\sigma = \left|\frac{T_\uparrow - T_\downarrow}{T_\uparrow + T_\downarrow}\right| T_\sigma$, which takes into account not only the relative fraction of one of the spins [2], but also the contribution of those spins to the electric current, finding that even for low values of magnetic field the system shows high polarization over a wide range of energies.

In addition, we found that the magnetoresistance, expressed as $MR = \left|\frac{I_{\uparrow,\downarrow} - I_{(B=0)}}{I_{(B=0)}}\right|$, where $I_\uparrow$and $I_\downarrow$ are the currents with spin-up (or) and spin-down respectively [2], generated by the application of an external magnetic field in direction perpendicular to the growth of the molecule (here $I_{(B=0)}$ represents the current without magnetic field) of the catechol, can reach different values depending on the variations of the applied magnetic field, the configuration and the interactions between the contacts and the molecular system.

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Layers and multilayers of ITO, AZO and ITO/AZO thin films grown by RF magnetron sputtering for the adjustment of their optical properties.

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Indium tin oxide (ITO) and Al-doped ZnO (AZO) thin films were grown on glass substrates using the rf sputtering technique, then multilayers of these two materials (ITO/AZO) were made alternating in 6-layers and 12-layers structures. Using SEM images, uniform and homogeneous AZO/ITO multilayers were observed, with an average thickness of 100 nm for each layer. The XRD results for the AZO thin film show a hexagonal wurtzite structure with a preferential orientation in the c axis, in the (002) plane, for the ITO film, the cubic structure of In2O3 with preferential (222) plane prevails. The band gap value obtained for the AZO and ITO single layers are 3.41 eV and 3.57 eV respectively. The ITO/AZO multilayer films demonstrated the highest transmittance in the visible region, while the AZO single-layer films exhibited the highest transmittance in the near-infrared region. The average optical transmittance was close to 80% in the UV-Vis region for the single layers and close to 75% for the multilayers. These findings could have significant implications for the development of thin film coatings for various applications, such as solar cells and displays.

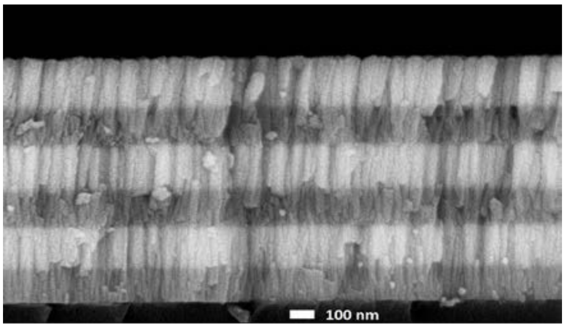

Fig. 1: Cross-sectional FESEM images of the growth of multilayers ITO/AZO thin films.

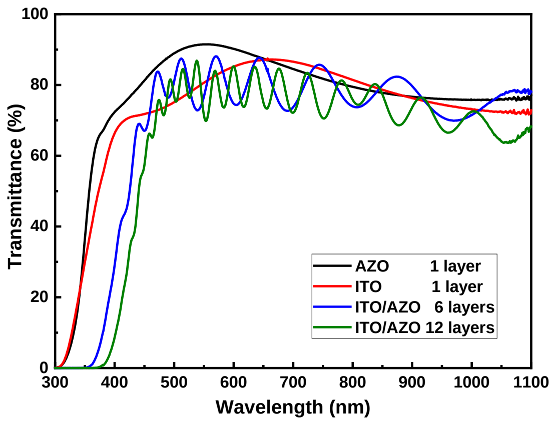

Fig. 2: Layers and multilayers transmittance spectrum of ITO, AZO and ITO/AZO thin film samples.

Non-zero Magnetoresistance at Room Temperature for a Manganite Tunneling Junction

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The discovery of the giant magnetoresistance (GMR) [1] in trilayers and superlattices of Fe and Cr lead to reduction of size and development of new read heads. One of the important features of this application is the use of the electronic spin in the conduction process. Afterwards, the colossal magnetoresistance, CMR, was discovered in manganites. Among the reasons why CMR takes place in manganites is that they are half metals; for such materials, only majority carriers are present at the Fermi level. Thus, when working with manganite-based magnetic tunneling junctions, MTJ, its tunneling magnetoresistance, TMR:

$$TMR = \frac{2P_1P_2}{1 - P_1P_2}$$

(where P_1 and P_2 are the spin polarizations of each of the ferromagnetic electrodes) equals a theoretical infinite value. In this paper, we present the TMR dependence on the temperature and on the magnetic applied field of tunneling junctions based on $La_{1-x}Sr_xMnO$. By including an exchange bias layer and by choosing a proper field direction, a magnetoresistance value different from zero at above room temperature is obtained for the sample grown on $NdGaO_3$ substrate, in contrast to that on $SrTiO_3$ substrate. This result is sheds some light on the influence of the lattice matching on the structure of the interfaces [2] and, as a consequence, on the transport properties of these MTJ.

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Reshaping the Jaynes-Cummings ladder with Majorana bound states [1]

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We study the optical properties of a hybrid device composed by a quantum dot (QD) resonantly coupled to a photonic mode of an optical microcavity and a Majorana nanowire [2]: a topological superconducting segment hosting Majorana bound states (MBSs) at the opposite ends [Fig. 1(a)]. In the regime of strong light-matter coupling, it is demonstrated that the leakage of the Majorana mode into the QD [3,4] opens new optical transitions between polaritonic states formed due to hybridization of material excitation with cavity photons [Fig. 2(d) and (f)], which leads to the reshaping of the Jaynes-Cummings ladder and can lead to the formation of a robust single peak at cavity eigenfrequency in the emission spectrum [Fig. 2(e)]. Moreover, weak satellite peaks in the low- and high-frequency regions are revealed for the distinct cases of highly isolated MBSs, overlapped MBSs, and MBSs not well localized at the nanowire ends.

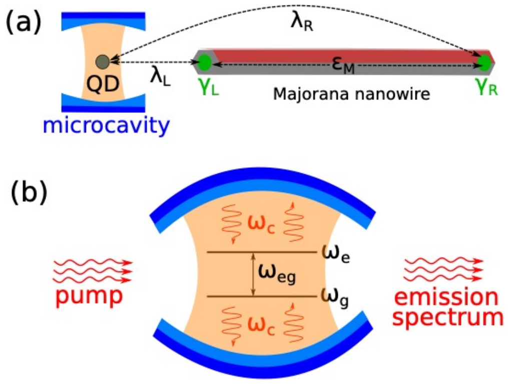

Fig. 1: (a) Sketch of the proposed device: a quantum dot (QD) embedded in an optical microcavity and coupled to a Majorana nanowire hosting Majorana bound states (MBSs) at its opposite ends (light green circles). (b) Optical transitions for a QD placed inside an optical microcavity. The dot interacts resonantly with a single-mode photonic field of the pumped cavity, with frequency brought in resonance with the energy of the optical transition.

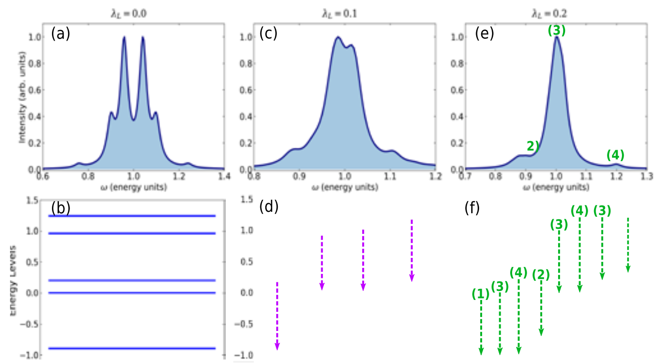

Fig. 2: Top: Normalized emission spectrum as a function of the frequency of emitted photon ω, for the situation in which the MBSs are well localized at the nanowire ends and do not overlap with each other, considering distinct values of QD-left MBS coupling λ_L. Bottom: Allowed optical transitions of the system which correspond to the peaks in the top panels, labeled by colored numbers.

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Effects of self-interactions of Coulomb over the relative stability of small copper clusters: Phonon calculations

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Despite the interest in copper clusters, a consensus on their atomic structure is still lacking [1,2]. Experimental observation of isolated clusters is difficult, and theoretical predictions vary widely [3,4,5]. The latter is because one must adequately describe the closed shell of d electrons both in its short- and long-range effects. Herein, we performed spin-polarized DFT calculations under the GGA approximation and including the Hubbard-U correction and the van der Waals forces to determine the relative stabilities of small copper clusters (Cu_N, N=3-6 atoms). We found that the vdW contribution is not relevant to determine the relative stability of the isomers. The inclusion of U represents the most relevant contribution to the energetic ordering of the Cu_N isomers, in terms of their relative stabilities, increasing values of U favor the most symmetric structures and also the planar forms. Our calculated binding-energies for the clusters agreed with the experimental values [6]. The predictions found with the previous approximations were contrasted with calculations that involve hybrid functionals. Finally, we calculated density of states of phonons for clusters studied and found that some clusters previously reported in the literature are not stables, also found that the phonon frequencies of isomers are in the range of 0 to 10 THz.

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A model for thermodynamic analysis of polariton condensation

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An important feature of polariton condensates is that they occur away from thermal equilibrium, in an open system where heat and particles are continually exchanged with reservoirs. In this work, we develop a few-level model of polariton condensation. This allows condensation to be understood as a form of heat engine and exposes the thermodynamic constraints on its occurrence [1].

Polariton condensation has been extensively analyzed in terms of kinetic equations [2-5]. Based on the collection of knowledge about polariton kinetics provided by these simulations and by experimental works, we constructed a model that captures the main processes involved in the buildup of a ground-state population of polaritons.

The model consists of a three-level system interacting with a field and connected to a hot and a cold thermal reservoir, that represents a non-resonant pump and the lattice phonons, as illustrated in Fig. 1a. This subsystem can drive a condensate, through polariton-polariton scattering, which produces work in the form of the coherent light emission from the microcavity. We point out that such behavior implies the presence of two heat baths, which must be at different temperatures so long as the cavity lifetime is not infinite, and furthermore implies there must be at least three energy levels in the working medium [6]. We obtain the phase diagram shown in Fig. 1d, where the two axes are the temperatures of the two baths, and the region under the curves is the condensed phase. Figs. 1b and c show the dependence of the condensate occupation on these temperatures and reveal that the transition is first-order.

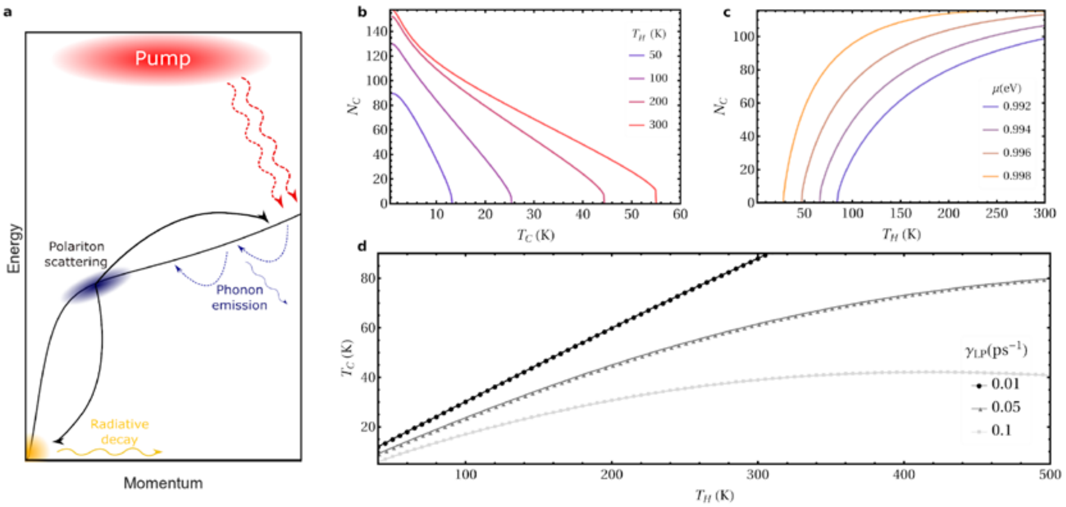

Fig. 1: Figure (a) has an illustration of the main processes that affect the polariton distribution. (b) and (c) show the occupation number of the condensate as a function of the temperature of the cold and hot reservoirs, respectively. And (c) shows the phase diagram of the condensate.

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Telecom-band single photons from functionalized carbon nanotubes coupled to an open cavity

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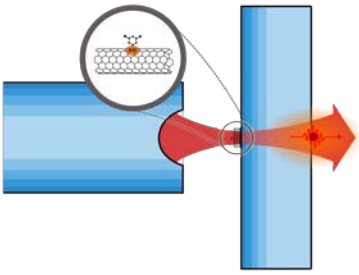

Fig. 1: Schematic drawing of a functionalized carbon nanotube coupled to an open fiber-based microcavity. The system generates telecom-band single photons with wavelengths around 1465nm.

Quantum light at telecom wavelengths is of fundamental relevance in science and technology. A promising room temperature source of telecom single photons are functionalized carbon nanotubes (CNTs) [1]. In this system, dephasing and spectral diffusion limit spectral purity and indistinguishability of the generated photons. Here, we overcome this limitation by coupling the emitters to a cavity [2]. We demonstrate spectrally narrow single photon emission at wavelengths around 1460 nm from single CNT defects coupled to a fiber-based Fabry-Pérot resonator. We operate the cavity at ambient conditions and in the regime of low Purcell enhancement. By changing the cavity length, we tune the emission wavelength over a range of tens of nm, and the power spectral density by a factor of six. The coherence time of the generated photons matches the cavity linewidth, which results in an increase of the expected dephasing-limited free-space indistinguishability by two orders of magnitude. Our results represent a step towards CNT-based sources of telecom-band single photons with high purity and indistinguishability.

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Effects of the exciton fine structure splitting on the entanglement-based quantum key distribution

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To generate pairs of entangled photons, quantum dots can be initialized in the biexciton state, so that consecutive radiative decay from the biexciton to the exciton state and then from the exciton to the ground state, as shown in figure 1(a), yields strongly correlated photon pairs. An adequate cascade decay requires three bound levels with total angular momentum J=0 (biexciton state), J=1 (exciton state), and J=0 (ground state), respectively, as long as the J=1 state is three-fold degenerated (magnetic quantum numbers m=-1, m=0 and m=1) [1].

The fine structure splitting (FSS) between exciton states J=1 m=1 and J=1 m=-1, present in most samples due to the so-called electron-hole exchange (EHEX), affects the entanglement of the photon pairs generated by the biexciton-exciton-ground state cascade decay. Therefore, the FSS between the ideally degenerated single exciton states, plays a significant role in the characteristics of the correlation between the entangled photons and must be considered in the quantum information processes they are used for [2].

As for quantum information applications of entangled photon pairs, the protocol BBM92 is arguably the most used scheme for quantum key distribution (QKD) based on polarization entanglement [3]. It allows detection of eavesdropping activity without the need of verification through measurements of Bell's inequalities.

In this work, we study the effects of the FSS on the fidelity of a key transmitted by means of the BBM92 QKD protocol, when the used entangled states are generated in a cascade decay, subject to not negligible EHEX interaction.

We find how the magnitude of the FSS directly impacts the quality of the distributed key, in such a way that a non-negligible FSS, even if modest, may significantly damage the fidelity of the distributed key.

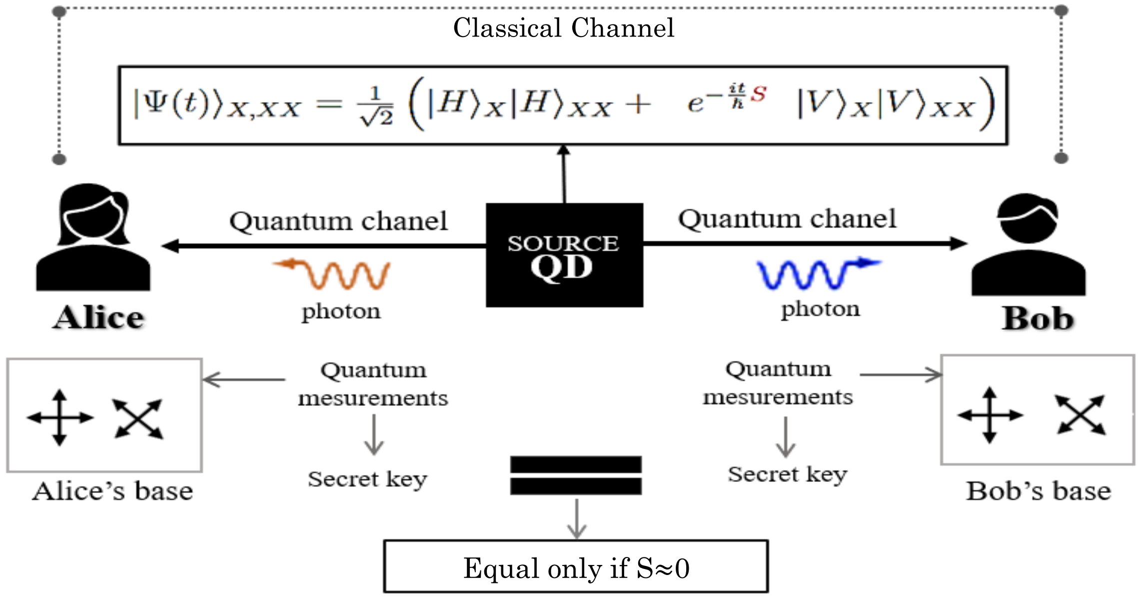

Fig. 1: Schematics of the influence of the FSS on the QKD by the quantum information protocol BBM92, with S as the magnitude FSS.

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Engineering the properties of exciton polaritons in an atomically-thin semiconductor

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Planar microcavities with embedded semiconducting materials can host exciton polaritons (polaritons herein), which are hybrid light-matter quasiparticles consisting of excitons (bound electron-hole pairs) and photons [1]. The formation of polaritons occurs when the energy exchange rate between the excitons and the cavity photons, which is related to their coherent coupling strength, is sufficiently large. By taking advantage of the interactions between the excitonic component one can create an interaction driven macroscopically coherent quantum state on a microchip, i.e., a polariton condensate [2], potentially enabling dissipationless information technologies [3,4] and low-threshold polariton lasers [5], which could function at room temperature thanks to the low effective mass of the photonic component.

A promising platform for polaritonics is the family of atomically-thin transition metal dichalcogenide crystals (monolayer TMDCs) [6,7], which host excitons that strongly interact with light and are sufficiently stable for room temperature applications. In this talk, I will demonstrate various methods to engineer the properties of WS_2 polaritons in all-dielectric planar microcavities. The developed techniques allow us to observe ballistic transport in monolayer WS_2 at room temperature [8], engineer strong spatial confinement for the polaritons substantially enhancing their macroscopic coherence and ground state population [9], and transition between exciton polaritons and polaron polaritons [10] in the same device without applying an external gate voltage. This was achieved with our recently developed passivation and protection technology for monolayer WS_2 [11], which utilises ultrathin Ga_2O_3 glass that forms on the shell of liquid gallium [12]. Further, I will introduce a new concept to invert the dispersion of polaritons, by taking advantage of dissipative coupling between the excitons and photons [13]. The latter causes level attraction and can arise from the interplay between exciton-phonon scattering and photon losses. We realize the anomalous dispersion experimentally by integrating monolayer WS_2 into all-dielectric microcavities with a positive exciton-photon detuning, where the group velocities of the propagating polaritons point to the opposite direction of their momentum, confirming their true negative mass character. Some of the presented techniques could also be applied to other exciton hosting material system, e.g., perovskites, and for integrating TMDs into different photonic resonators, e.g., optical BICs (bound-states in the continuum) [14].

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Optically driven rotation of exciton-polariton condensates

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The rotational response of quantum condensed fluids is strikingly distinct from that of classical fluids, especially notable for the excitation and ordering of quantized vortex ensembles [1]. Although widely studied in conservative systems, the rotational dynamics of open-dissipative superfluids such as exciton-polariton condensates remains largely unexplored, as incoherent driving at microwave frequencies is required to nucleate significant angular momentum.

We experimentally rotate a spontaneously formed and unconfined polariton condensate by pumping with an "optical paddle", constructed from the time-dependent interference of two spatially structured, GHz frequency-offset laser modes [2]. The acquisition of angular momentum exceeding $1\hbar$/particle with rotation frequencies up to 8 GHz is directly imaged and characterized. At sufficiently large frequencies, optical rotation is observed to drive the *deterministic nucleation and capture of multiple quantized vortices* with a handedness controlled by the pump rotation direction (Fig. 1). Strong qualitative agreement with Gross-Pitaevskii numerical modelling provides clarification of the mechanism of angular momentum acquisition and the observed vortex dynamics, and necessitates both conservative and open-dissipative terms to capture the stirring behavior. Further, this system is shown to be suitable for the study of ordering phenomena of dense quantized vortex matter in a non-equilibrium regime.

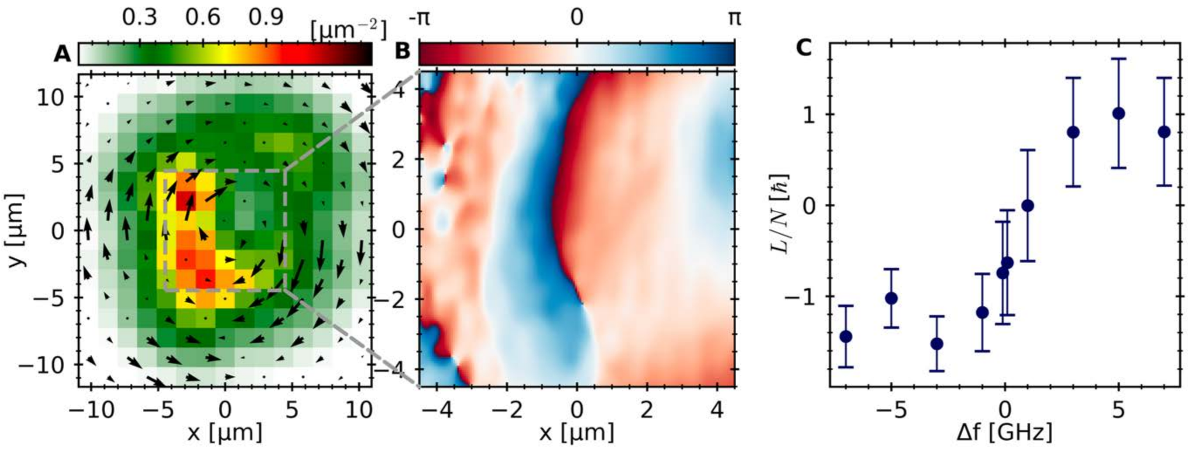

Fig. 1: Polariton rotation (A) Polariton density profile and azimuthal vector flows induced by a nonresonant pump. (B) Reconstructed phase map around axis of rotation, showing a vortex near the center. (C) Angular momentum per particle as a function of rotational frequency.

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Intersubband optical responses in semiconductor quantum wells with non-conventional confining potentials and spatially-dependent effective mass

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Intersubband-related nonlinear optical coefficients are calculated for GaAlAs semiconductor quantum wells with non-conventional potential profiles, explicitly considering the spatial variation of the electron conduction effective mass. Among the different shapes of confinement considered there are the hyperbolic Fibonacci potential, the four-parameter exponential type potential, as well as deformed hyperbolic potentials. Numerical solution of the resulting effective mass band equation is performed using the finite element method. Among the nonlinear optical coefficients evaluated are the absorption and nonlinear optical rectification ones.

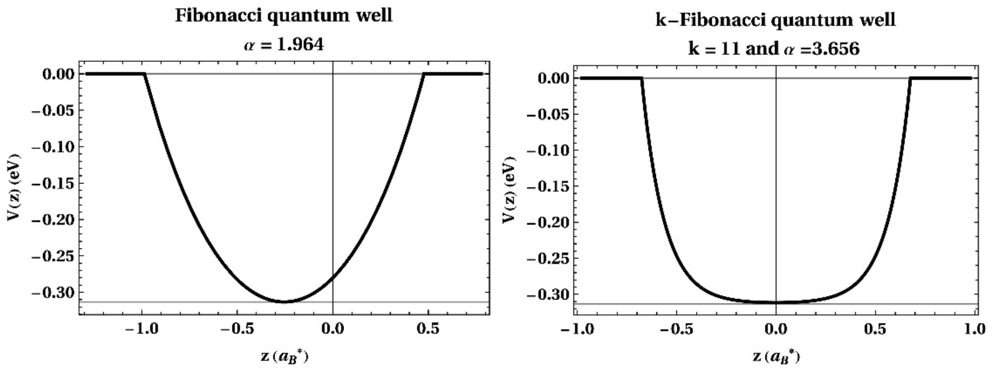

Fig. 1 (Left) ϕ-Fibonacci GaAs/AlGaAs finite-depth quantum well potential as a function of position (in effective units) for well region width of 16 times the lattice constant. (Right) k-Fibonacci quantum well ($k = 11$) with the same configuration. Maximum barrier height corresponds to Al molar fraction $x = 0.33$

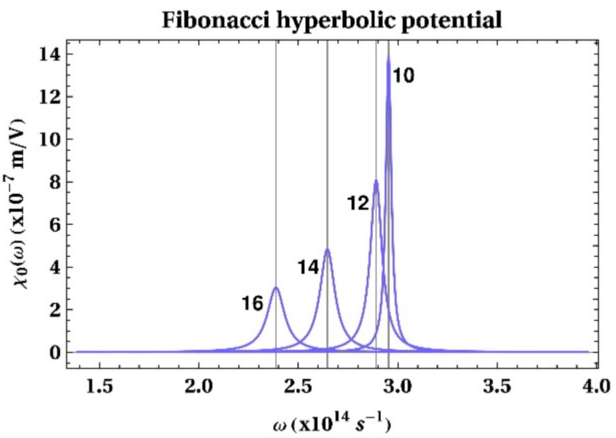

Fig. 2: The coefficient of nonlinear optical rectification related to intersubband transitions in a GaAlAs Fibonacci hyperbolic quantum well. Curve labels indicate the top width of the structure as multiples of the lattice constant.

Optovalleytronics with warped or tilted Dirac cones

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Together with familiar degrees of freedom such as charge, momentum and spin, quasiparticles in crystals can possess an additional flavour known as a valley quantum number arising from the underlying lattice symmetry. The most celebrated example are electrons in graphene which co-exist at the same energy in two inequivalent Dirac cones in momentum space. There is a rising prospect of using this valley quantum number as a basis to encode information for new “valleytronic” device applications where quasiparticles of a given valley are selected, transported effectively through the material, and detected. Here, we demonstrate how to optically control the valley degree of freedom both in graphene [1] and in the emerging class of gapless materials that host tilted Dirac cones [2,3], retaining the superior graphene-like transport properties.

In graphene, the trigonal warping effect leads to the spatial separation of charge carriers belonging to different valleys upon linearly-polarized high-frequency photoexcitation. Valley separation in gapped materials can be detected by measuring the degree of circular polarization of band-edge photoluminescence at different sides of the sample or light spot (optical valley Hall effect). We demonstrate that the celebrated Rashba effect, caused by substrate-induced system asymmetry, leads to a strong anisotropy in the low-energy part of the spectrum for graphene on carefully-chosen substrates. This results in optical valley separation by a linearly-polarized excitation at much lower frequencies compared to the high-energy trigonal warping regime.

In two-dimensional materials with tilted Dirac cones (8-*Pmmn* borophene being the best-known example), the inequivalent Dirac cones are skewed in opposite directions, allowing electrons from different valleys to move to opposite sides of the light spot. The gapless nature of these materials, in addition to their superior transport properties, provides broadband operation frequencies and tunability via an applied back gate voltage. We demonstrate [3] that optical valley control is possible at arbitrarily low photon frequencies including the deep infrared and terahertz regimes with full gate tunability via Pauli blocking. This work pushes the emerging field of two-dimensional tilted Dirac cone materials in a new direction by highlighting their potential to become the ideal platform for tunable broadband optovalleytronic applications.

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Piezoelectric Control of Acoustic and Optical Properties

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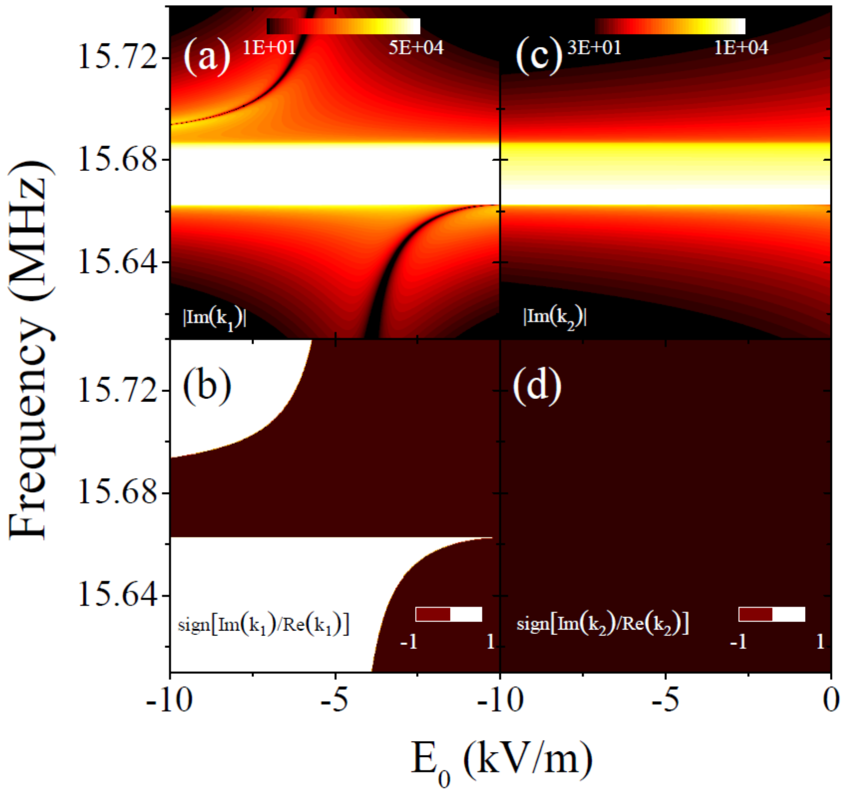
The influence of piezoelectricity on acoustic gain in electric-field biased zincblende semiconductors is discussed using the theory of Hutson and White [1] but extended to account for the dispersion effect of the permittivity. It is shown that when the permittivity approaches zero the acoustic gain of an incoming sound wave may be enhanced by several orders of magnitude with important implications for active sound control or parity-time synthetic phononic materials [2]. In the second part of the talk, the influence of strain, spontaneous polarization, and piezoelectricity on I-V curves and dipole oscillator strengths of III-V ZnO/GaN p-n diodes in the wurtzite and zincblende crystal phases are elucidated. It is verified that piezoelectricity is the dominant factor for tuning of I-V curves and dipole oscillator strengths in wurtzite and zincblende structures (the latter grown along the [111] direction) but the tuning effect vanishes for zincblende structures grown along the [100] direction.



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Multi-Qubit Photonic Devices

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Semiconductor quantum dots are one of the best on-demand sources of single and entangled photons to date, simultaneously merging the highest brightness and indistinguishability of the emitted photons. They are, therefore, among the strongest candidates for practical single-qubit quantum photonic devices. However, to exploit the full advantage of quantum physics, multi-qubit photonic devices are vital. This talk will present our approach to realizing practical multi-qubit photonic devices for quantum photonic networks based on novel crystal-phase quantum dots in nanowires.

Electrically-Driven Plasmons in Metal-Insulator-Semiconductor Tunnel Junctions: The Role of Si Amorphization

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We study electrically-driven plasmons (EDP) in metal-insulator-semiconductor (MIS) tunnel junctions consisting of Au-Alumina-(p)Silicon heterostructures which we fabricate using electron-beam lithography. While most of the reported work in the field of EDP pertains to metal-insulator-metal (MIM) junctions, MIS devices received much less attention. An MIS tunnel junction is an attractive research subject because of the additional properties that are introduced when using semiconductors: the magnitude and type of doping (p or n), the presence of an energy gap, and the bending of the bands, all of which influence the EDP process. In principle, inelastic tunneling can occur either into the conduction or to the valence band. The first case involves tunneling from a continuum of states in the metal to a continuum of available states in the semiconductor conduction band. The resulting spectrum should therefore be similar to that observed in MIM devices. Tunneling to the valence band, on the other hand, involves an almost-discrete final state of low-density holes. The EDP spectrum in this case is expected to be a step function, reflecting the Fermi Dirac distribution of the electrons in the metal.

Here we study the optical spectrum and Transmission Electron Microscope (TEM) cross-sections of MIS devices as a function of applied bias. We show that amorphization of the silicon layer at low voltages, and breakdown defects in the insulating layer at high voltages, determine the spectral and spatial properties of the emitted light. This is manifested in a uniform distribution of the light intensity over the mesa area with an MIM like spectrum at low voltages, and a spotty emission pattern with a spectral plateau at high voltages.

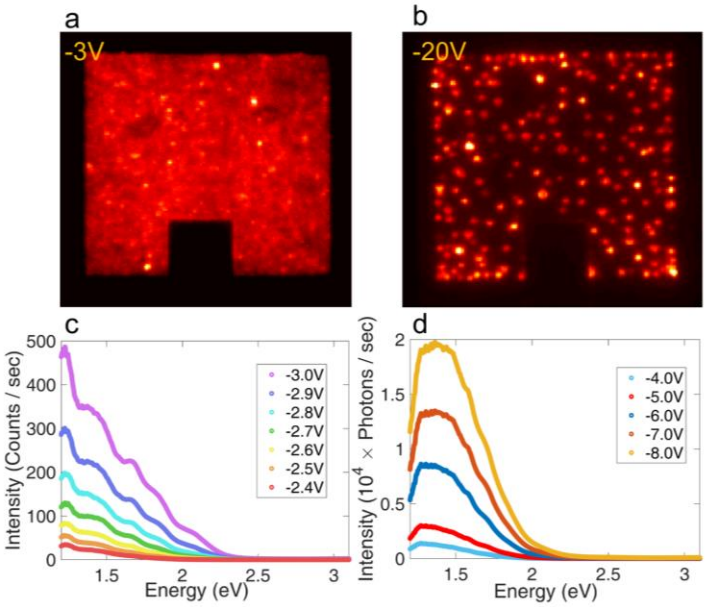

Fig. 1: Uniform to spotty emission transition, reflecting a permanent change in the tunnel junction. Up until a threshold voltage, -3V in this device, emission is uniform and spectra resemble those of MIM junctions. When the threshold is exceeded, the appearance of diffraction-limited hotspots dominates the emission and the spectra change from exhibiting linear MIM-like behavior to spectral plateaus.

Effects of high pressures on the structural properties of the GeO_2-PbO glassy system with incorporation of Au nanoparticles for applications in optoelectronic devices

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Within the list of appealing host materials for their luminescent properties, vitreous systems such as GeO_2-PbO stand out for their structural and optical properties in the fabrication of optoelectronic devices: laser lighting, optical memory, data storage, optical bioimaging and optical amplifiers, optical communication, etc [1-4]. In this work, we report the effects of high pressure (up to 7.7 GPa) on the structural properties of GeO_2-PbO glass superficially doped with Au nanoparticles. The glass synthesis was performed by the melt-quenching method, whilst the ionic implantation technique was used for the Au nanoparticles. Simulation by molecular dynamics and complemented by two experimental techniques, as ellipsometry and UV-Vis spectroscopy, shows irreversible changes in the structure of the studied vitreous system. Surface plasmon resonance of the Au nanoparticles reveals a shift towards high energies after the high-pressure experiments, which are related to the formation of nanoseed-like particles. Our results could be an indicator to optimize optoelectronic devices for laser applications and optical amplifiers.

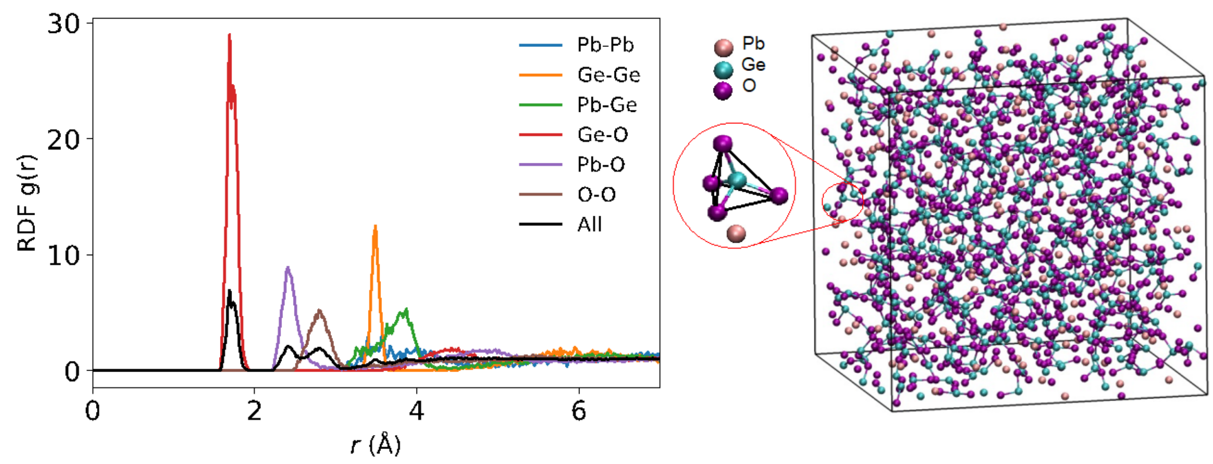

Fig. 1: In left, radial distribution function (RDF) of an amorphous Ge2-PbO system.

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Effect of external fields on the electronic and optical properties in ZnTe/CdSe and CdSe/ZnTe spherical quantum dot

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A theoretical analysis of the electronic and optical properties of a ZnTe/CdSe and CdSe/ZnTe core/shell quantum dot was carried out (Fig. 1). In the first system there is confinement of the electrons in the shell, and in the second, the confinement occurs in the core. The Schrödinger equation, under the effective mass approximation, was solved using the finite element method (FEM), using the Comsol Multiphysics program in the 2D symmetric axes module, obtaining the eigenvalues and eigenfunctions, under magnetic fields and applied electric fields (both fields in the z-direction). In Fig. 2, it is shown that the presence of the magnetic field, in both systems, is to increase the confinement of the electron, therefore there is an increase in energy.

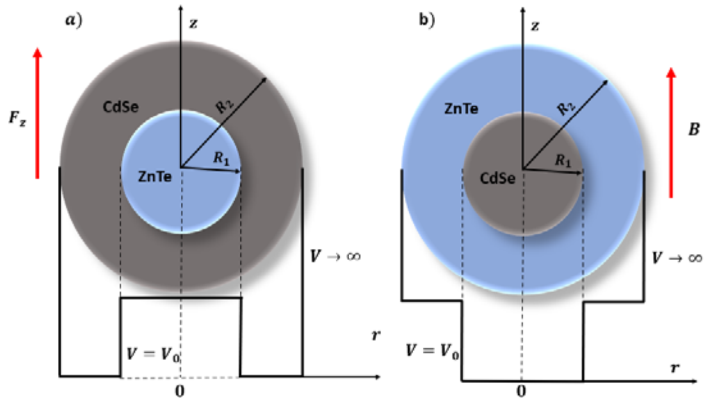

Fig. 1: Cross section of spherical quantum dot a) ZnTe/CdSe, b) CdSe/ZnTe. The dimensions of the QD, the applied axial electric and magnetic field are given along with the confinement potential dependent on r.

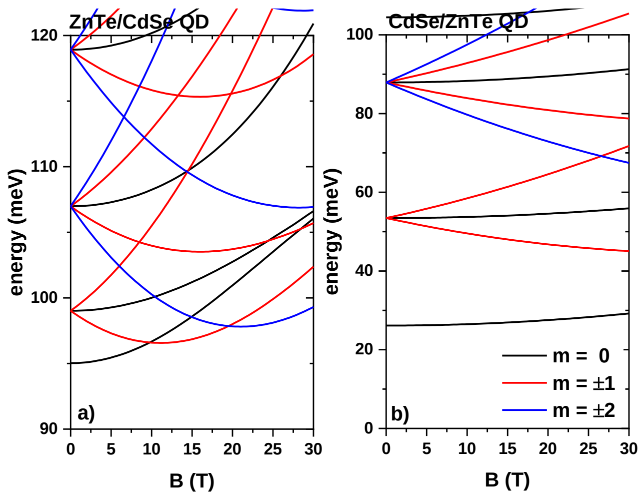

Fig. 2: Electronic states in a spherical core/shell quantum dot as a function of the magnetic field, a) ZnTe/CdSe, b) CdSe/ZnTe, with R_1 = 10 nm, R_2 = 15 nm. The curves shown are for different values of the quantum number m and without external electric field effects.

Tuning radiative heat transfer via surface-polaritons hybridization

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In this work, we show how the near-field radiative heat transfer (NFRHT) is modulated via the hybridization of surface-polariton modes. Two systems are considered: 1) A cavity formed by two parallel slabs at different temperatures. Each slab is made of a semiconductor coated with porous Bi. 2) Each slab is a metamaterial made of silica and decorated with spherical LiH nanoparticles.
For the first system, we show that Fano resonances are excited. These resonances arise from the coupling of surface plasmon-polaritons and surface phonon polaritons sustained by each layer, and strong suppression and enhancement of the total spectral heat flux in specific frequency regions is shown. The mode hybridization is explained in terms of polarization matching, and causes the opening of a thermal band gap. This is a region of the electromagnetic spectra where no radiative heat is emitted.
In the second system, the periodic arrangement of the nanoparticles aids in the construction of an effective dielectric function that is anisoptropic allowing for the excitation of surface and hyperbolic modes. These modes can be tuned by changing the periodicity of the array of nanoparticles and their aiding in the enhancement of the NFRHT.
The details of the results of this work are presented in Refs. [1] and [2]

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Nonlinear optical absorption coefficients in elliptical Core/Shell/Shell quantum dots: Effects of electric and magnetic fields

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Theoretical investigation about to the nonlinear optical absorption coefficients in elliptical GaAlAs/GaAs/GaAlAs quantum dots is considered in the presence of the external electric and magnetic fields. In addition, we take in account the effects of the dot size, the incident photon energy, and the width of the structure of the confined electron region on the optical properties are also investigated. The region of confinement in this quantum dot corresponds to the intersection of three differently centered semiconductor ellipses. The energy levels and wave functions of the electron in the nanostructure with a finite core/shell/shell type-potential are calculated numerically with the effective mass approach using a complex eigenvalue formalism through finite element methods[1]. Calculations of optical properties are performed within the framework of compact density matrix approach and iterative method[2]. The results reveal significant dependence of the nonlinear optical absorption coefficients with the ellipses dimensions and intensities of the applied electric and magnetic fields.

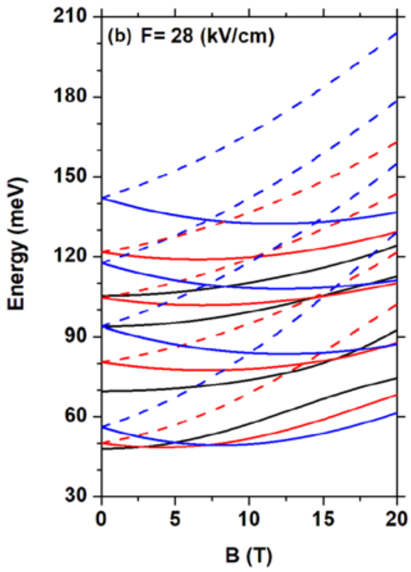

Fig. 1: Electron energy levels as a function of the magnetic field in elliptical GaAlAs/GaAs/GaAlAs quantum dots, with an external fixed electric field applied.

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Resonances of the optical responses of the inter-subband transitions in GaN/InGaN/AlGaN/GaN quantum wells

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The electron confinement potential in a GaN/$In_yGa_{1-y}N$/$Al_xGa_{1-x}N$/GaN quantum well is determined by the lattice constant differences of the barrier and well materials. These differences produce self-induced electric fields and self-polarizations in the heterostructure. The dependence of the energy with the concentration of the materials of the well and the barrier is analyzed, in addition their lengths of both are varied[1,2]. These effects on the inter-subband transitions for the confined states of the electron are studied. The energy values and wave functions are calculated within the effective mass approximation as a function of the coordinates and the enveloping wave function technique is used. Due to the asymmetric profile of the generated potential, the states can be very well located for different configurations of the width of the quantum well, the width of the barrier and the concentration itself. The resonances of the optical responses are found to be in the near infrared spectrum. Finally, nonlinear optical responses show a significant wavelength shift (3000 nm to 1000 nm),

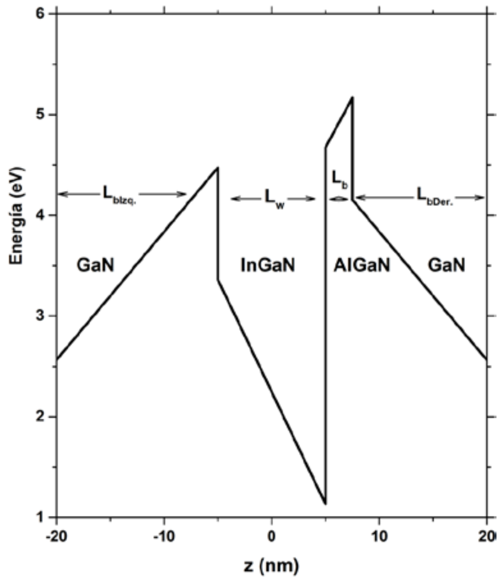

Fig. 1: GaN-$In_yGa_{1-y}N$-$Al_xGa_{1-x}N$-GaN quantum well profile.

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Quantization of exciton polaritons in shallow optical traps

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The growth technology of semiconductor microcavities is constantly being improved. Now it is possible to grow high-quality samples in which the lifetime of the polaritons is tens of picoseconds, and the diffusion length is tens of microns. The long diffusion length of polaritons makes it possible to study polariton condensates, which are spatially separated from optical pumping. In this case, the properties of the condensate turn out to be closer to ideal, since the interaction of the condensate with the reservoir of nonradiating excitons is strongly suppressed in this case. Various geometries are used to create localized condensates, including sample etching, application of stress etc. One of them is completely optical, when pumping is done in the form of one or two concentric rings. In this case, photoproduced excitons play a dual role. The main part of the excitons creates a confining potential for polaritons due to the exciton-polariton repulsion. Only polaritons have a large diffusion length. Excitons in the reservoir have a very short diffusion length and the confining potential almost repeats the shape of the optical pump. On the other hand, this reservoir serves as a pump for the polariton condensate. As an example, in the case of pumping with two concentric rings, it is possible to create condensate in the form of a narrow strip sandwiched between the outer and inner rings. Such condensates are interesting, in particular, because they can have nonzero orbital angular momentum, just like their light emitted by them. However, as our studies have shown, a simpler trap geometry with one outer ring can also be used to form a condensate with a nonzero AOM [1,2]. We observe that during nonresonant optical pumping of a sample with a microcavity by a ring with a diameter of about 15–20 micrometers, radiation of a polariton condensate of a quite definite shape is observed.

When the pump power is just above the threshold of a polariton laser, spectrally narrow radiation is observed, corresponding to one level of size quantization. Depending on the diameter, this can be either the first level, for traps with a slightly smaller diameter, or one of the excited levels for traps with a larger diameter. As the pump power is increased, several states begin to shine simultaneously, which differ in energy by less than 1 meV. By scanning the condensate image across the slit of the spectrometer and measuring the spectrum with vertical resolution, we can separately obtain the spatial distribution for all emitting levels. The thus reconstructed spatial image of the condensate radiation for a trap with a diameter of 20 microns at an optical pump power of 10 mW is shown in Fig. 1. By the shape of the radiating states, it can be assumed that they are the levels of radial quantization of the polariton condensate, since the number of minima increases for each next level when moving in the radial direction. Moreover, the spatial distribution of levels coincides very closely with what one-particle quantum-well levels should look like in a cylindrical trap (Fig. 2). The solution of the two-meter Schrödinger equation gives states close to the levels of an electron in a hydrogen atom: s, p, etc. The ring current state is in this case a superposition of two basic states with px and py. The height of the potential created by optical pumping is such that, depending on the pump power, from one to four size-quantization levels are placed in the trap. Calculations show that, depending on the height of the potential barrier, the level energies should slightly shift with a change in the pump power, but the spectral resolution of the setup did not allow us to detect this. It is interesting to note that, depending on the diameter of the trap, when the generation threshold is exceeded, both the ground state and the excited ones can ignite first. We attribute this to the different overlap between the exciton reservoir and the size-quantized state. It is always maximum at the top of the levels in the trap, and for traps of a larger diameter it differs significantly from zero only for the top levels. At a certain pump power, the second level turns out to be upper and the state with nonzero angular orbital momentum begins to shine. Thus, the trap diameter allows us to change the relative efficiency of optical pumping at different levels. Peak power allows you to change the height of the potential barrier and the number of quantum-well levels. This creates an effective basis for further study of polariton currents.

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Topological insulator vertical-cavity laser array: From fundamental aspects to potential application

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Topological Photonics is an emerging and novel field of research, adapting concepts from condensed matter physics to photonic systems adding new degrees of freedom. After the first demonstrations of topological photonic insulators, the field has moved on to study and exploit the inherent non-hermiticity of photonic systems and the interplay with their topological nature. With the envisaging [1] and realization [2] of topological insulator lasers it became possible to exploit topological effects to facilitate injection locking of arrays of semiconductor lasers. Topological insulator lasers have now been realized using a variety of platforms and designs as a means to efficiently couple and phase-lock extended arrays of lasers to behave like one single coherent laser. The major drawback so far is that the emission appears in the plane of the topologically protected light propagation, thus hindering light extraction. By designing a topological system which employs out-of-plane emitters such as evanescently coupled Vertical Cavity Surface Emitting Lasers (VCSELs), we can successfully separate the emission direction of the individual lasers from the propagation direction of the topologically protected mode in-plane ensuring the topological protection.

In this work, we present the first experimental demonstration of a topological insulator VCSEL array [3]. Using the crystalline topological insulator model and ensure topological mode protection at the interface of a compressed and stretched hexagonal lattice. In contrast to a range of topological photonic systems, here the topological protection is virtually independent of the wavelength or direction of lasing. The individual emitters are arranged in a lattice array measuring a few tens of microns, with each site emitting vertically, allowing for an efficient light collection and resulting in a powerful coherent laser beam. Spatial interference measurements of the topological mode using an inverted Michelson interferometer confirm coherent laser emission of the array, spectrally within the topological bandgap. This highlights that that the full array of 30 emitters displays an extended coherent mode emitting at a single wavelength. Our experiments demonstrate that the topologically protected in-plane transport can force the predominantly vertically oscillating emitters to act as one single coherent laser.

Furthermore, we will discuss concepts to introduce electrical injection. We will present electrically driven lasing from a topological lattice structure consisting of p-i-n doped GaAs/AlAs-based distributed Bragg reflectors surrounding a cavity region hosting InGaAs quantum wells [4].

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Towards lattices of interacting polariton condensates carrying vorticity

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We realize and study spatially arranged coupled vortices excited in microcavity exciton-polariton system [1]. For this, the non-resonant excitation laser profile is shaped with a reflective phase-only spatial light modulator, which allows for imprinting a honeycomb array of Gaussian beams onto semiconductor microcavity [2], as shown schematically (with white circles) in Fig. 1. We tune the size of the unit cell and the excitation density such as to form polariton condensates, confined in the lattice cells. The performed measurements of the condensates phase reveal formation of numerous vortices of topological charge $l = \pm 1$. To understand this observation, we study the formation of vortices in the building blocks of the lattice – single cell, 2&3-cell structures. We conclude that the condensates pumped above critical intensity tend to spontaneously acquire an opposite orbital angular momentum in each adjacent pair of cells. This leads to multistable behavior of the system arranged in triangular geometry, and resembles well-known geometric frustration phenomenon.

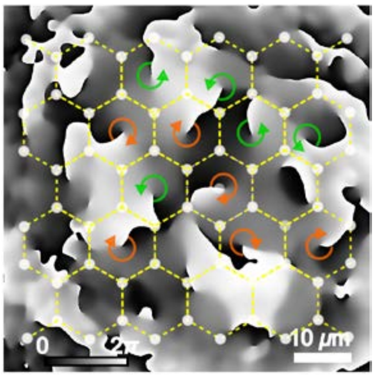

Fig. 1: Measured spatial phase of the optically trapped condensates excited nonresonantly by honeycomb array of Gaussian spots (see white circles) reveals numerous vortices of $l = \pm 1$ (green and orange arrows respectively).

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Dual band generation and wavelength-switchable fiber soliton laser mode-locked based on monolayer graphene

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We generate simultaneously polarization-depend mode-locked Erbium-doped fiber laser based on monolayer graphene at 1556-nm band and 1533-nm. The experimental setup consist all-fiber ring cavity of 0.355-m long Erbium-doped fiber (EDF) as a gain medium pumped by a 980-nm laser diode, using a sample on monolayer graphene in a D-shaped fiber as a saturable absorber with 98% loss insertion in the ring cavity [1, 2]. The experimental results show in Fig.1(a) the output spectrum when the laser is not pulsed for a particular polarization state. On the other hand, in Fig. 1(b) when we change the polarization state using MPC 1556 nm-band is mode-locked with a spectral width of 6.1 nm and the 1533 nm-band operates to CW (continuous-wave). After changing the polarization state 1536 nm-band is mode-locked with an 8 nm spectral width and the 1556 nm–band operates to CW, as can see in Fig. 1(c). Finally, A third configuration of the MPC is realized to reach dual-band operation centered at 1533 nm and 1556 nm with spectral widths around 2.4 and 6.5 nm respectively (see Fig.1d). In the case of the Dual Band, it represents an important finding [3–5] due to its multiple applications in telecommunications, such as the creation of tunable lasers.

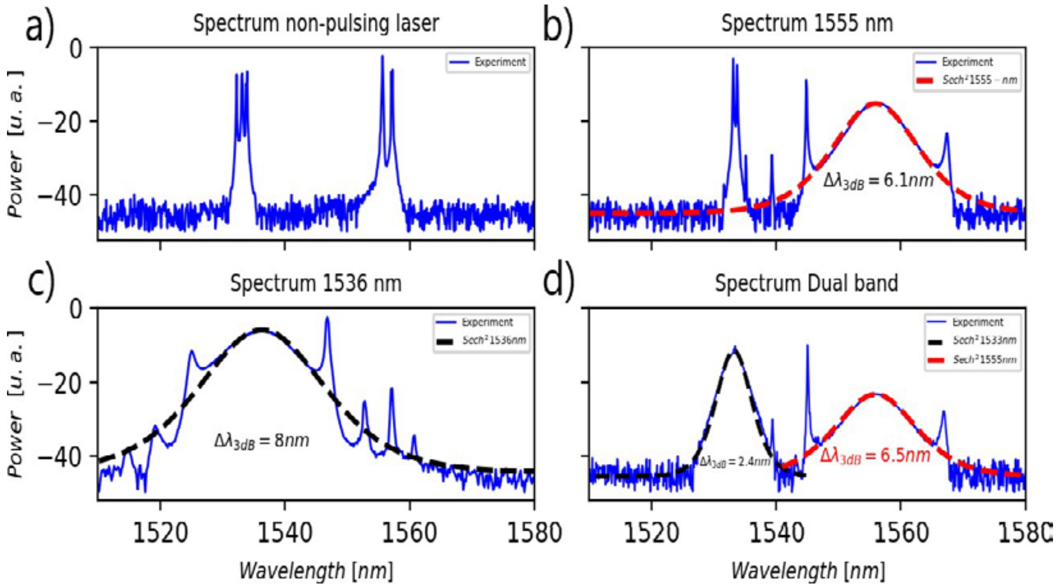

Fig. 1: a) The initial spectrum of non-pulsing laser with average power $P_m = 110$ μm, b) Spectrum centered to 1556 nm with $P_m = 124$ μm, c) Spectrum centered to 1536 nm with $P_m = 100$ μm and d) Spectrum of Dual-band generation.

Acknowledgments

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Circular Bragg grating cavities for semiconductor quantum dot based quantum technologies

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In this presentation, we will summarize recent progress made within our group and plans on device development with self-assembled quantum dots intended for quantum repeater and quantum computer applications [1]. A particular emphasis will be on semiconductor quantum dots embedded in circular Bragg grating cavities [2,3]. For scalability, spatially deterministic placement of quantum dots in bullseye cavities is pursued and techniques for tuning by electric and strain fields are implemented. To apply electric fields, a new device design for electrically contactable circular Bragg grating cavities in labyrinth geometry is employed [4]. We report on the challenges experienced in obtaining high performance devices based on circular Bragg grating cavities and figures of merits achieved, outlining the prospects for these devices in quantum technology applications.

We are grateful for financial support of this work by the German Federal Ministry of Education and Research (BMBF) within the projects Q.Link.X, QR.X, MHLASQU, PhotonQ and QD-E-QKD. Expert technical assistance by Silke Kuhn, Adriana Wolf and Margit Wagenbrenner is gratefully acknowledged.

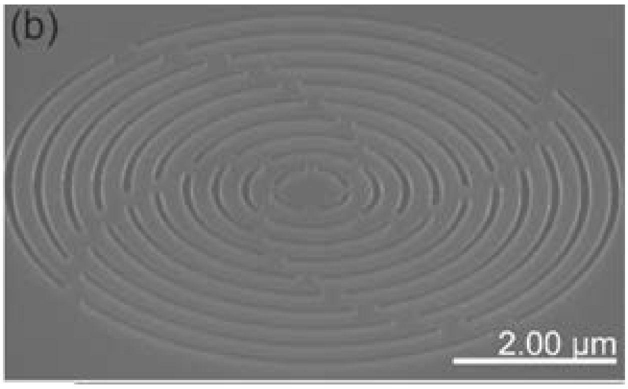

Fig. 1: Circular Bragg grating cavity in labyrinth geometry for electrical contacting.

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Nonlinear optical properties in hexagonal $GaAs/GaAl_{0.3}As_{0.7}$ quantum wires: Donor impurity, electric, and magnetic field effects

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Intraband energy transitions of an electron in $GaAs/GaAl_{0.3}As_{0.7}$ hexagonal quantum well wires in presence of external magnetic and electric fields are presented. In addition, the effects of wire size and the presence of a shallow donor impurity are calculated. Calculations are in the effective mass approximation and include the linear and nonlinear corrections to the optical absorption coefficient and to the relative changes to the refraction index coefficient. In Fig. 1 are shown the core/shell structure dimensions and the direction of the applied external fields. The electron energy levels and their corresponding wave functions are obtained via a finite element method using, supported by the licensed COMSOL-Multiphysics software. The results reveal a significant dependence of the calculated physical properties on the dimensions of the quantum wire, the presence of the impurity, and the intensities of the applied electric and magnetic fields.

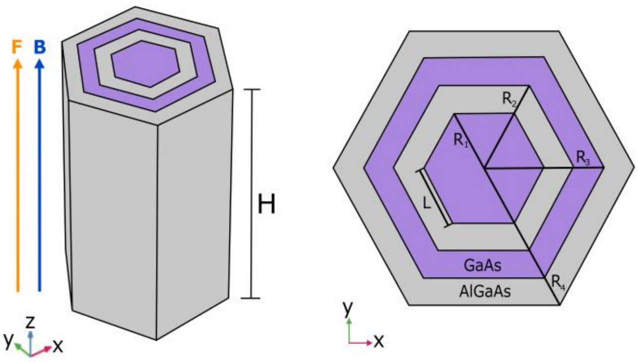

Fig. 1: Geometry of the hexagonal $GaAs/GaAl_{0.3}As_{0.7}$ quantum wire, indicating the parameters H, R_1, R_2, R_3, R_4, and L. The external magnetic and electric fields, B and F, are shown.

Electric field influence on intraband transitions in delta-doped quantum wells

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We consider nanosized layered semiconductor heterostructures, which combine a rectangular quantum well with an impurity delta-layer within the well and superimposed external electric field applied in perpendicular direction to the layers. We use silicon as a well material and silicon-germanium alloy for the barrier with a shallow donor impurity for the delta layer positioned inside the well. Optical transitions between the first confined subbands of such structures correspond to the Terahertz part of the spectrum, which is both perspective in applications and problematic in implementation in modern optical electronics [1].

In our previous works [2] (and references there) we showed that delta-doped quantum wells make possible regulation of such optical transition energies by varying ionization degree of impurity inside the delta layer that allows tuning of working frequencies of possible optical devices based on such configuration. Here we add to the concept a transversal electric field that can be varied and provides an additional tuning parameter.

We study the tuning effects numerically using self-consistent method that embeds the calculation of impurity binding energy by Vinter [3] in the 20nm-wide well delta-doped to either center or near the barrier, with 20% of germanium in the barrier material. Both ionized impurity inside the well and external electric field distort the energy profile of the well and change the energy distances between subbands. The main characteristic of a tunability in our opinion is a range of energies for the transitions between the ground and first excited subband within the well for the reasonable magnitudes of delta layer ionization degree and external electric field. Also, we take into account and analyze variations of impurity binding energy of the delta layer.

The results of our analysis demonstrate that: (i) the magnitude of impurity binding energy can change up to 7 times for some parameter combinations; (ii) the concurrence between the external electric field and ionized impurity effects may lead to non-monotonous behavior of ground to first excited state transition energy with the applied bias; (iii) the biggest tuning range achieved is from 2 to 18 meV for 10 kV/cm.

Our results can be useful for the creation of a new type of tunable active or passive semiconductor optical devices working in terahertz range.

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Narrow band filters designed from hybrid quasi-periodic photonic crystals with a single defect layer.

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We report the transmission spectra and the electric field amplitudes propagating in hybrid quasi-periodic multilayer photonic structures. We consider the case of the combination of periodic (BM) (Bragg-like) and quasiregular layered components. The non-periodic sequences used to simulate the quasiregular regions are of the Fibonacci type (FB). The corresponding hybrid structure (HS) is formed by concatenating BM(N)-FB(N)-BM(N), where N means the number of periods (sequence order) used for the BM (FB) structure. The single defect layer (DL) is considered in the middle of two HS (HS-DL-HS). Optimizing the parameters (Order of sequence, number of BM layers, thickness, and refractive index of DL) permits us to obtain Narrow band filters. The manipulation of these parameters fixes the number of photonic band gaps (PBGs) and the position of the transmission peaks. Furthermore, the existence of a selectively localized behavior of some optical modes in the structures is discussed.

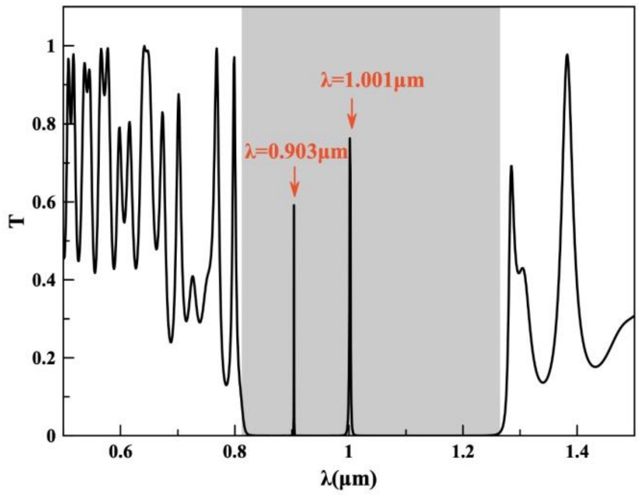

Fig. 1: The transmission spectra of hybrid quasi-periodic photonic crystals with a single defect layer (DL) HS-DL-HS (where HS → BM(4)FB(2)BM(4), see **Fig. 2**).

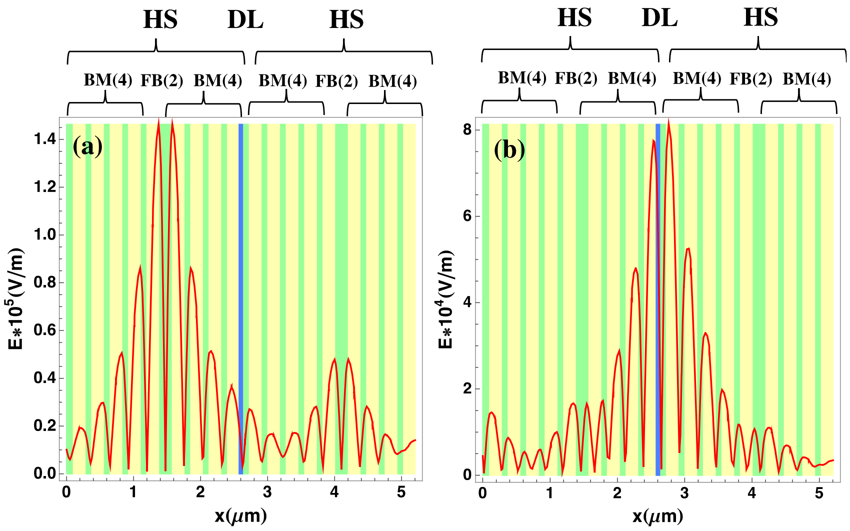

Fig. 2: Spatially localized electric field amplitudes of defect-like modes propagating in hybrid quasi-periodic multilayer photonic structures as shown in **Fig. 1:** **(a)** λ=1.001μm and **(b)** λ=0.903μm .

Exciton-polaritons with halide perovskites

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Recently, semiconducting lead halide perovskites with a composition of ABX3 (where A is commonly CH3NH3+ (MA+) or Cs+; B is Pb2+; X is Cl−, and Br−) have emerged as contenders to GaAs for polaritonic but at room temperature, due to their large exciton binding energy, high photoluminescence (PL) quantum yield, tunable bandgap and high room-temperature nonlinear interaction strength23. With chemical vapour deposition (CVD), single-crystalline inorganic halide perovskites have shown polariton condensation. However, due to the limitations of the current growth methods and the fragile nature of perovskites, only small single crystals can be integrated into the optical cavities. Critically, the small sizes prohibit the studies of the large-scale phenomena, such as soliton formation, XY spin Hamiltonian, and topological effects, due to the limited lattice size and the restricted propagation lengths.

In this talk, I will first introduce our approach [1] to overcome the above size limitation by direct solution growth of various types of large are halide perovskite single crystal inside optical nanocavities. Due to the uniform confined environment, the solution growth approach shows uniformity, comparable to the MBE-grown GaAs quantum well, enabling submillimeter size large single crystals with superb excitonic quality. These crystals with strongly interacting Wannier-Mott excitons allowed us to successfully demonstrate a polaritonic XY spin Hamiltonian with all-inorganic perovskite $CsPbBr_3$ at room temperature. Further, we show that a lattice with a large number of coherently coupled condensates up to 10 x 10 can be achieved this is an important step towards the ultimate goal of realizing a room temperature polaritonic platform on par with MBE-grown GaAs at low temperatures. In addition, we show that the dispersion of the perovskite system has unique advantages for future studies on synthetic non-Abelian gauge fields and topological physics.

Lastly, I will also introduce our recent two work using halide perovskite on electrically pumped polariton [2] and polariton superfluidity [3].

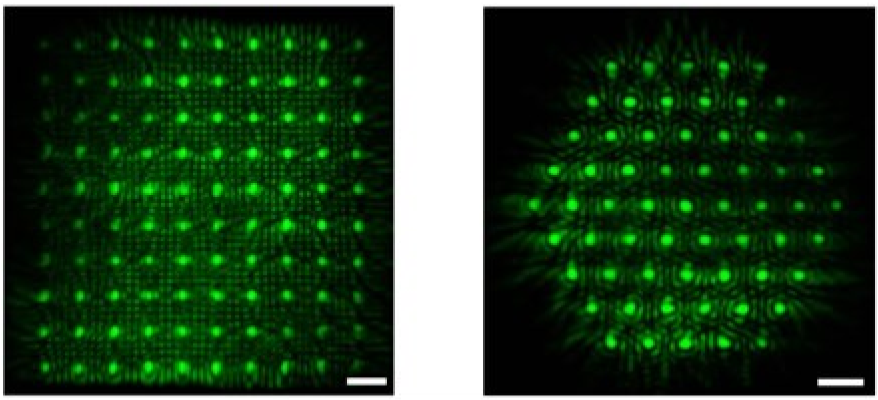

Fig. 1 Left: Time-integrated real-space image of a 10×10 polariton lattice with antiferromagnetic coupling. Right. Time-integrated real-space image of a triangular polariton lattice with ferromagnetic coupling. Scale bars, 5 µm

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Stochastic Single Shot Polariton Condensate Polarization Pinning at High Temperatures

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Many body spin systems are known to be suitable for probing complex combinatorial and optimization problems [1,2]. They also provide useful insight into collective interacting spin behaviors [3]. Optically trapped exciton-polariton condensates [4] have been observed to spontaneously magnetize to either of the two spin states [5] providing the foundation for applications such as random number generators. Considering practical real-world applications, we require high temperature operation of a single trapped polariton condensate. We resolve the degree of spin polarization in optically trapped polariton condensates in a GaAs system [6]. Using a pulsed laser excitation scheme, we resolve every-single pulse realization. Under circularly polarized excitation, we observe the strong degree of polarization of trapped polariton condensates present for temperatures up to 170K and following the polarization of the pump. For linearly polarized excitation, the stochastic spin bifurcation of trapped polariton condensates persists with high degree of polarization for temperatures up to 130K. The stochastic nature of the spin polarization of trapped polariton condensates under linearly polarized excitation is revealed by the statistics enabled by the pulsed excitation scheme with single-pulse temporal resolution detection scheme. We measure the dependence of the stochastic spin bifurcation on temperature, and the excitation power and polarization.

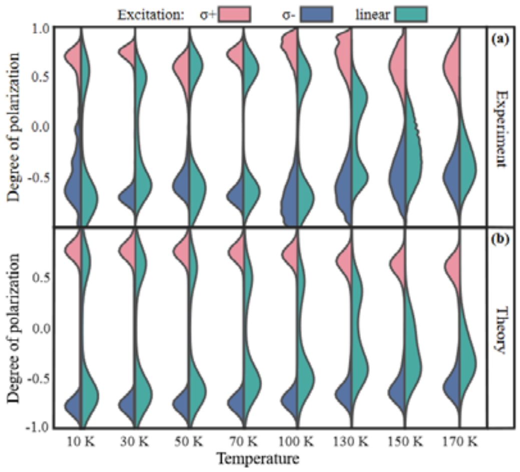

Fig. 1: Distribution of the polarization degree s_z as a function of temperature under various excitation schemes in experiment (top) and theory (bottom)

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Copper nanowires synthesis for transparent conductive thin films

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The present work focuses on the synthesis of copper nanowires (CuNWs) suitable for its use in thin films as transparent conductive electrodes as a replacement for ITO where it is used in fields such as photovoltaics, electronic devices, and OLEDs. Nowadays, the requirements for novel technologies include flexible thin films, with good electrical and optical properties where ITO is successful in the last two, it is insufficient for flexible devices. Indium scarcity and ITO brittleness lead to look for alternatives. Thus, CuNWs are investigated as an option due to their good conductivity, high transparency, affordability, and abundance of copper reserves on earth. Synthetized CuNWs thin films of 70 nm diameter in average and lengths larger than 100 µm were obtained using spin coating on glass substrates. Ascorbic acid and glucose were investigated as reductant agents along with the concentration of the precursor ($CuCl_2 \cdot 2H_2O$) for each one to find the optimal conditions for getting as many CuNWs as possible by means of hydrothermal synthesis. As a first step, the works of Zhang *et al* [1]. and Wang *et al.*[2] were followed but the research of Kang *et al.* [3] was the most helpful in this regard. Finally, samples were analyzed using DRX, SEM, UV-VIS spectroscopy, and sheet resistance.

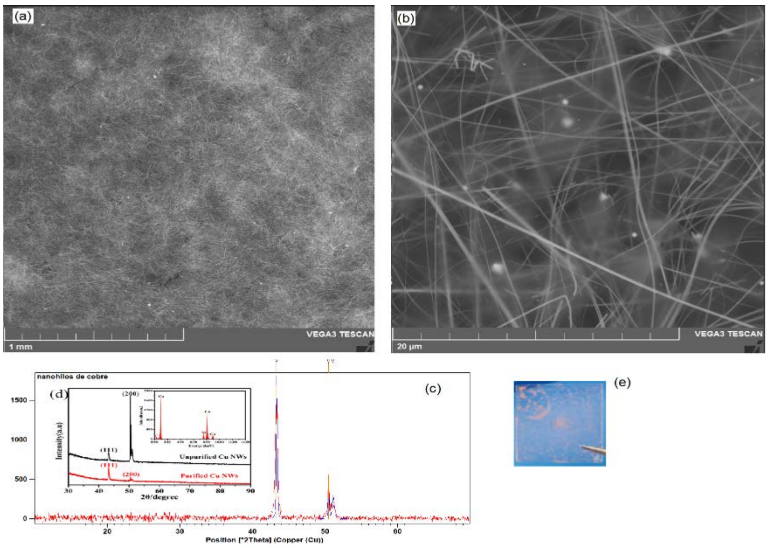

Fig. 1: (a) and (b) SEM images . (c) DRX results (d) Results of Kang et al. From[3] (e) First thin film fabricated

Figure 1 shows two images taken in scales of 1mm (a) and 10 µm (b) after the purification process. (c) corresponds to the DRX results where metallic copper was obtained with peaks in $2\theta = 43.3$ and 50.4°. (d) also shows a DRX pattern for comparing the results to those of Kang *et al.* (e) is the first thin film obtained using spin coating where it can be concluded that further work is necessary to obtain homogeneous films.

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