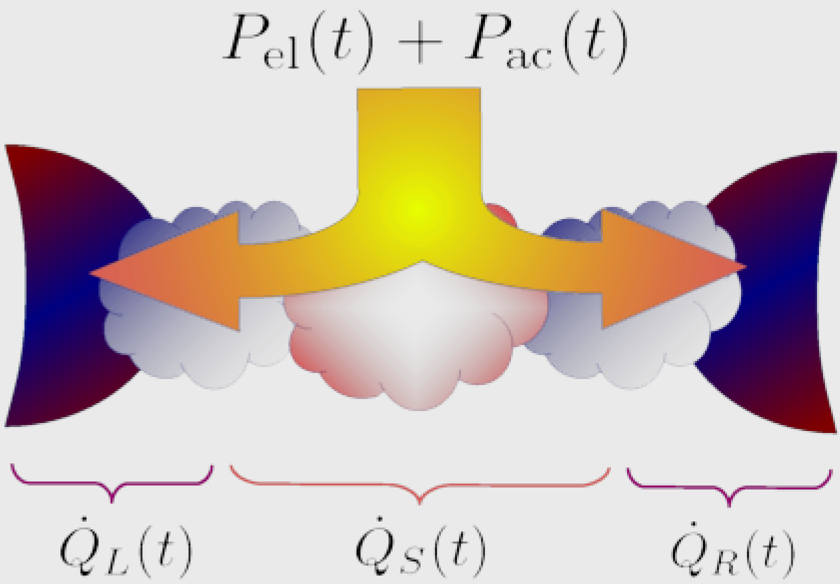
Periodic Energy Transport and Entropy in Quantum Electronics

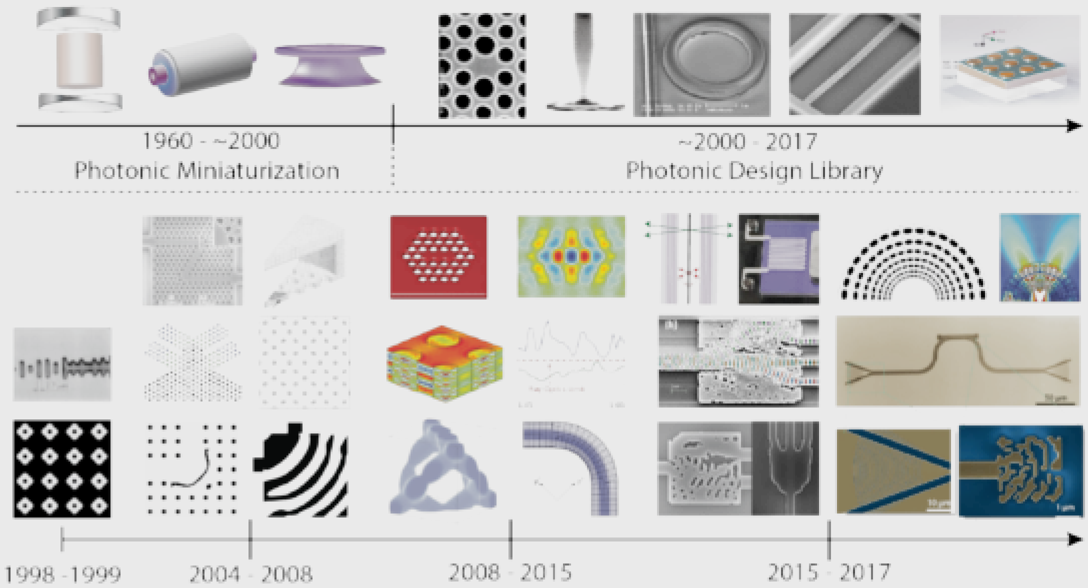


Title: Periodic Energy Transport and Entropy in Quantum Electronics.
When: Monday, July 2, (2018), 12:00.
Place: Department of Theoretical Condensed Matter Physics, Faculty of Sciences, Module 5, Seminar Room (5th Floor).
Speaker: David Sánchez, Institute for Cross-Disciplinary Physics and Complex Systems IFISC (UIB-CSIC), Palma de Mallorca, Spain.

Most of the recent literature on quantum thermodynamics focuses on static fields and the resulting stationary transport effects. However, there is a growing interest in analyzing thermodynamic properties of quantum conductors in the presence of time-dependent potentials. In this case, dynamics is the main objective of the theory as fluxes and responses depend explicitly on time. It is also of paramount importance for potential applications to discriminate which portion of the energy invested to operate quantum devices is amenable to be used and which one is wasted by dissipation. This distinction is at the heart of thermodynamics and is conventionally addressed in quasistatic processes where the system under study is very weakly coupled to the reservoirs. In quantum electronics, nevertheless, the generic situation is to have the driven structure strongly coupled to the rest of the circuit, which plays the role of a reservoir.

Here, I will discuss in detail the energy transfer through a mesoscopic conductor attached to fermionic reservoirs. The energies of the sample evolve with time due to the coupling with nearby ac gate terminals. Deep inside the reservoirs, electrons relax their excess energy and the baths can thus be considered in local thermal equilibrium. We will also consider the entropy production in the whole system and will identify the different terms arising in the redistributed energy and heat. Importantly, when the energies shift slowly with time the response is adiabatic and an exact Joule law can be demonstrated for the time domain. Our analysis is completely general and does not rely on the particular approach followed to evaluate the relevant dynamical quantities.

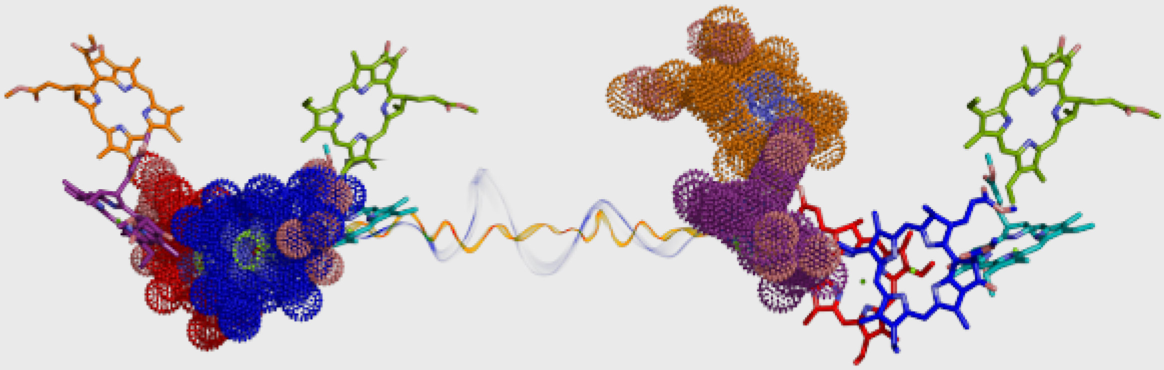
Recent Developments and Applications of Inverse Design in Nanophotonics



Title: Recent Developments and Applications of Inverse Design in Nanophotonics.
When: Thursday, June 21, (2018), 12:00.
Place: Department of Theoretical Condensed Matter Physics, Faculty of Sciences, Module 5, Seminar Room (5th Floor).
Speaker: Alejandro W. Rodríguez, Department of Electrical Engineering, Princeton University, USA.

Large-scale optimization (or inverse design) in photonics has begun to shape the landscape of on-going experiments and research problems in areas ranging from light harvesting to optical communication. In this talk, I will survey recent developments and applications of inverse design techniques in nanophotonics, including computer-aided discovery of photonic structures designed to greatly enhance nonlinear optical processes such as frequency generation, or that exhibit high-order exceptional points. Exceptional points, which are complicated spectral degeneracies in non-Hermitian systems, can lead to modifications in the local density of states or spontaneous emission rate of emitters embedded in optical resonators (a generalization of the familiar Purcell enhancement figure of merit) and can also lower the power requirements of certain nonlinear processes. Time permitting, I will also show that inverse design techniques can be exploited to enhance heat transfer between nanostructured surfaces separated by sub-micron vacuum gaps, which depends strongly on the shapes and materials of the bodies. We find that in a variety of conditions, the discovered structures lead to enhanced radiation rates which follow the expected scaling with material susceptibility derived recently from bounds based on energy conservation (a generalization of the familiar blackbody limits to situations involving sub-wavelength structures).

The Quantum Design of Photosynthesis for Bio-Inspired Solar-Energy Conversion



Title: The Quantum Design of Photosynthesis for Bio-Inspired Solar-Energy Conversion.
When: Wednesday, June 13, (2018), 12:00.
Place: Department of Theoretical Condensed Matter Physics, Faculty of Sciences, Module 5, Seminar Room (5th Floor).
Speaker: Elisabet Romero, The Institute of Chemical Research of Catalonia (ICIQ), Tarragona, Spain.

Photosynthesis holds the key to the efficient use of solar energy using abundant and renewable materials. At the heart of Photosynthesis, the pigment-protein complex photosystem II reaction center (PSII RC), performs charge separation with near unity quantum efficiency despite its highly disordered energy landscape, and thus converts sunlight to electrochemical energy.
To achieve this amazing feat, the PSII RC exploits The Quantum Design Principles of Photosynthetic Charge Separation1-2, complementary and interrelated solutions to

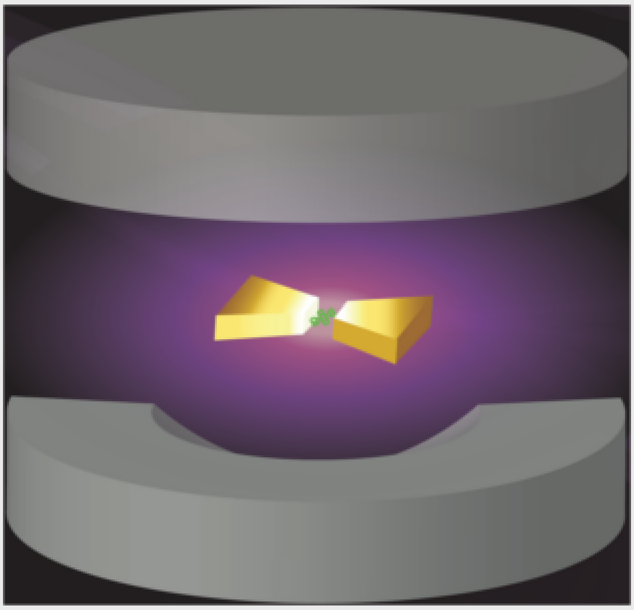
ensure rapid forward and irreversible transfer of energy and electrons within a disordered and fluctuating environment. Thus, these principles provide a guide for the rational design and construction of systems able to transfer energy and electrons with high efficiency and in the right direction. In this talk, I will present these principles with a focus on the role of vibronic coherence and discuss my view on how to implement coherence in bio-inspired systems with the potential to perform efficient energy and electron transfer.

References

Romero, E., Augulis, R., Novoderezhkin, V. I., Ferretti, M., Thieme, J., Zigmantas, D. & van Grondelle, R. Quantum coherence in photosynthesis for efficient solar-energy conversion. Nat. Phys. 10, 676-682 (2014).

Romero, E., Novoderezhkin, V. I. & van Grondelle, R. Quantum design of photosynthesis for bio-inspired solar-energy conversion. Nature 543, 355-365 (2017).

Enhancing Quantum Coherence of Organic Molecules with Nanophotonic Structures



Title: Enhancing Quantum Coherence of Organic Molecules with Nanophotonic Structures.

When: Monday, June 11, (2018), 12:00.

Place: Department of Theoretical Condensed Matter Physics, Faculty of Sciences, Module 5, Seminar Room (5th Floor).

Speaker: Diego Martín Cano, Nano-Optics Division, Max Planck Institute For The Science Of Light, Erlangen, Germany.

The optical coherence lies at the heart of quantum phenomena that arise from the interaction between light and matter. To maintain and control such coherence is crucial for the development of quantum optical technologies, since it is intrinsically involved in the generation of nonclassical features that allow surpassing the capabilities of classical systems. One of the experimental approaches to access this quantum coherence is to use the interaction of light with electronic transitions that are available in solid state emitters. However, the coherence of these transitions is commonly hindered by additional interactions arising from the materials that host the emitters.

In this talk I will present some of our theoretical attempts to propose nanophotonic structures that ameliorate such loss of quantum coherence, with an emphasis on aromatic hydrocarbons in organic crystals [1,2], and to provide fundamental measures to test it [3,4]. These efforts include the exploration of nanostructures embedded in optical microcavities, which we show they provide access to stronger coherent interactions and suppression of emission quenching near metals [5].

References

H. Kelkar, D. Wang, D. Martín-Cano, B. Hoffmann, S. Christiansen, T. Utikal, S. Götzinger, V. Sandoghdar, Phys. Rev. App., 4, 054010 (2015).

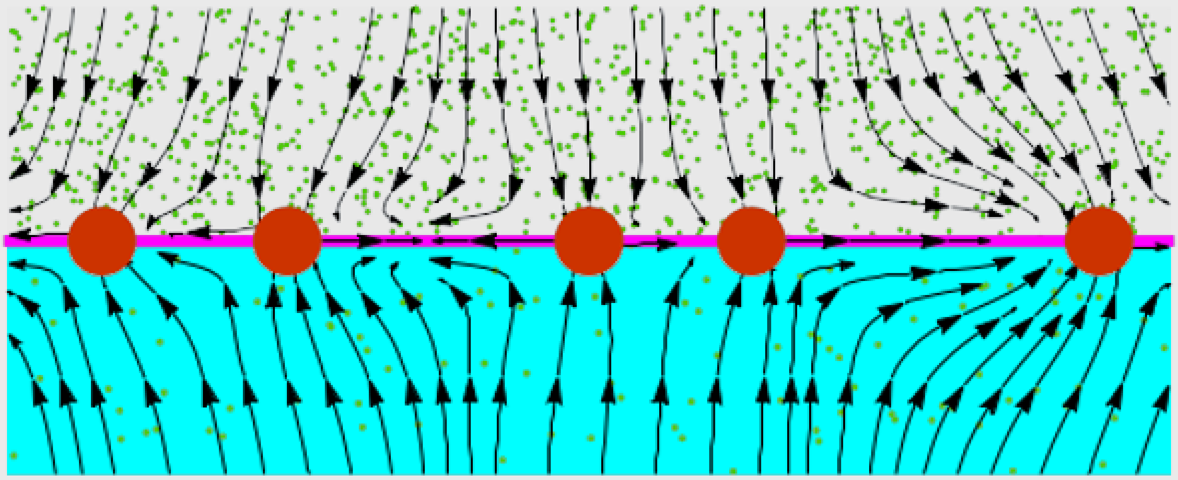
D. Wang, H. Kelkar, D. Martin-Cano, T. Utikal, S. Götzinger, V. Sandoghdar, Phys. Rev. X, 7, 021014 (2017).

D. Martín-Cano, H.R. Haakh, K. Murr, M. Agio, Phys. Rev. Lett., 113, 263605 (2014).

H. Haakh, D. Martín-Cano, ACS Photon., 2, 1686 (2015).

B. Gurlek, V. Sandoghdar, D. Martín-Cano, ACS Photon., 5, 456 (2018).

Active Colloid at a Fluid Interface



Title: Active Colloid at a Fluid Interface.

When: Tuesday, June 05, (2018), 12:00.

Place: Department of Theoretical Condensed Matter Physics, Faculty of Sciences, Module 5, Seminar Room (5th Floor).

Speaker: Álvaro Domínguez, Atomic, Molecular and Nuclear Physics Department, Universidad de Sevilla, Spain.

The last years have witnessed the growing interest on active colloids, i.e., of colloids made of particles that exhibit chemical activity: this activity induces gradients in the ambient fluid and thus drives a self-induced colloidal dynamics. This kind of systems have attracted attention both as a paradigm of nonequilibrium physics and for its potential applications.

In this talk, I will present recent theoretical work focused on a monolayer of active colloid formed at a fluid interface. A new phenomenology arises which is exclusive to the combination “activity + interface”, because the interface is also responsive to chemical gradients: the spatial variations of the surface tension induce Marangoni flows in the ambient fluids that manifest themselves as an effective interaction between the colloidal particles and between these and the interface. At the mean-field level, this interaction is analogous to two-dimensional Newtonian gravity. A particularly interesting result is the existence of “pseudoequilibrium” particle distributions in the monolayer describing the Marangoni-induced coexistence of thermodynamic phases. I will finally discuss the experimental evidence and the feasibility of observing the theoretical predictions.

References

H. Masoud and M. Shelley, Phys. Rev. Lett., 2014, 112, 128304.

A. Dominguez, P. Malgaretti, M. N. Popescu and S. Dietrich, Phys. Rev. Lett., 2016, 116, 078301.

A. Dominguez, P. Malgaretti, M. N. Popescu and S. Dietrich, Soft Matter, 2016, 12, 8398b, 8406.
A. Dominguez and M. N. Popescu, arXiv:1804.01451.

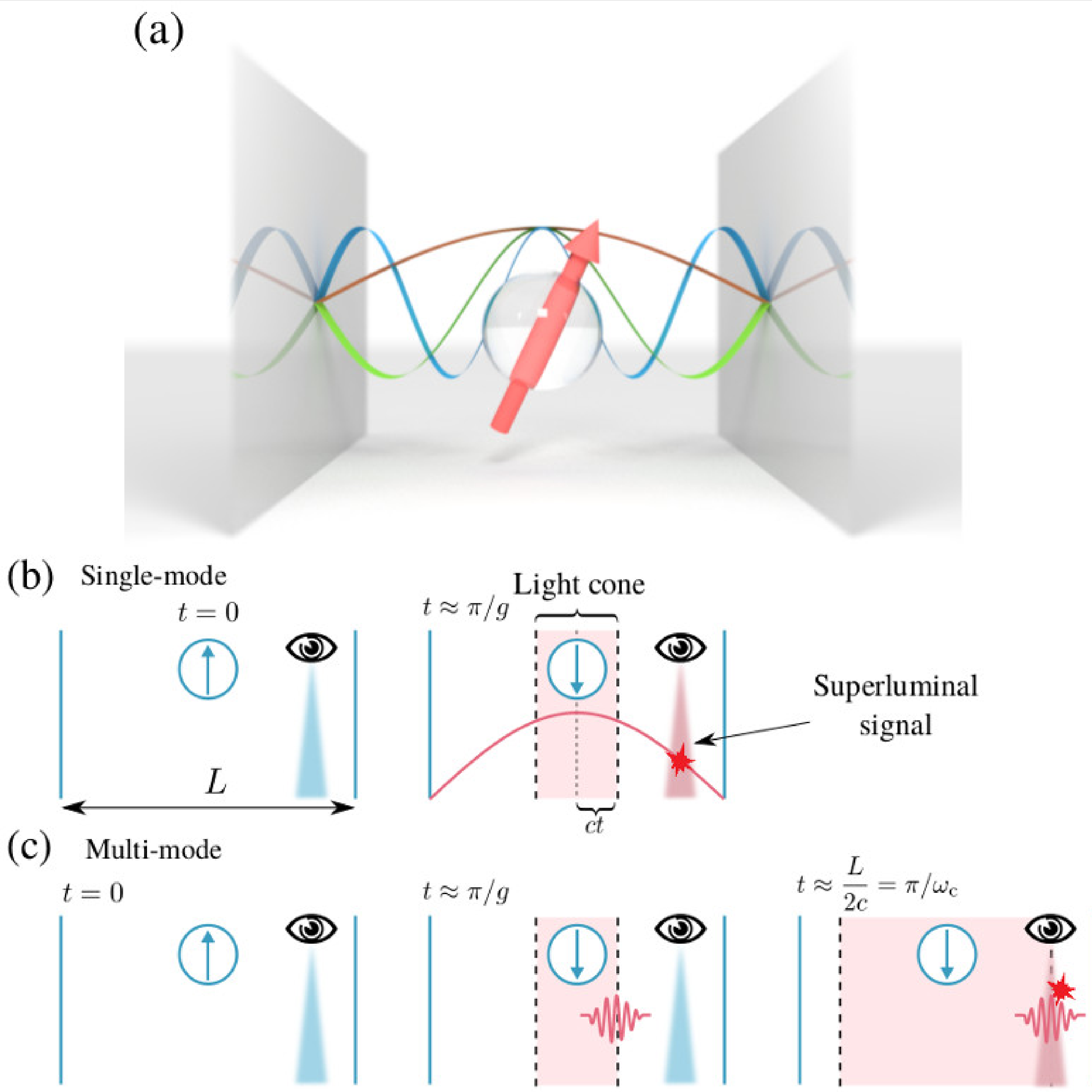
FET Open Project CATCH-U-DNA: Capturing non-Amplified Tumor Circulating DNA with Ultrasound Hydrodynamics

This multidisciplinary suggest replacing the labor-intensive, occasionally biased and costly PCR method currently used for the detection of genetic cancerigenous markers with a simple, non-PCR based DNA quantification method. The suggested system will exploit the ability of acoustic waves in the surface of quartz resonators to probe the hydrodynamic shape of surface-bound molecules, rather than its mass. The scientific challenge to be addressed is to push the limit of detection to the zM range obviating the need to use a polymerase for DNA amplification. The technological challenge is to fabricate ultra sensitive acoustic devices and capture with high efficiency very low numbers of DNA present in a complex medium on the device surface. These ambitious goals will be achieved by developing novel probes with liposomes and nanoparticles of tailor-made sizes and shapes for enhanced acoustic response; exploiting high frequency acoustic devices up to the GHz range; and, employing magnetic beads with microfluidics for specific target-capturing and enrichment. The proof-of-principle will be demonstrated during the detection of circulating-tumor DNA (ctDNA), currently an area perceived by cancer researchers as the “Holy Grail” of future cancer diagnosis, prognosis and treatment. We intend to validate our integrated acoustic platform towards the detection of common mutations occurring in colorectal and lung cancers, i.e., KRAS, EGFR and BRAF in serum. We anticipate that the “CATCH-U-DNA” concept will set the foundations for a simpler, more sensitive and affordable diagnostic method, from which patients in both the developed and developing countries will greatly benefit. The consortium involves 7 groups (FORTH (Crete), BGU (Israel), AWS (Valencia), UOC (Universitary Hospital at Crete), Curie Institute (Paris), JOBST (Friburg) and UAM (Madrid).

The UAM group leaded by the IFIMAC member Rafael Delgado-Buscalioni in the Department of Theoretical Condensed Matter Physics, is in charge of the theoretical description of the probe dissipation, using hydrodynamic simulations to propose new ways to improve the sensitivity by increasing the dissipation. The detection of extremely low concentrations of DNA using ultra-sensitive acoustic probes targets will push the detection limit down to the zM range without PCR, produce highly selective and specific isolation of ctDNA targets in serum with the fluidized bed technology towards the final target: Demonstrate the simultaneous detection of 48 colorectal and lung cancer mutations from ctDNA.

We congratulate Prof. Rafael Delgado-Buscalioni.

Resolution of Superluminal Signalling in Non-perturbative Cavity Quantum Electrodynamics



gnalling in the single-mode Rabi model. a) Schematic view of a qubit embedded in a perfect 1D cavity, together with the depiction of the three lowest cavity modes. When the qubit is only coupled to the fundamental mode, the system is described by the Rabi Hamiltonian. b) Violation of relativistic causality by the single-mode Rabi model in regimes where g ≈ ωc. An observer placed close to the cavity edge can retrieve information about the initial state of the TLS before light is able to reach its position. c) A multi-mode description is able to capture the spatio-temporal structure of the light field necessary to comply with causality.

Title: Resolution of Superluminal Signalling in Non-perturbative Cavity Quantum Electrodynamics.

When: Monday, May 21, (2018), 12:00.

Place: Department of Theoretical Condensed Matter Physics, Faculty of Sciences, Module 5, Seminar Room (5th Floor).

Speaker: Carlos Sánchez Muñoz, RIKEN Cluster for Pioneering Research, Wako-shi, Japan.

Recent technological developments have made it increasingly easy to access the nonperturbative regimes of cavity quantum electrodynamics known as ultrastrong or deep strong coupling, where the light–matter coupling becomes comparable to the bare modal frequencies [1].

In this talk, I will discuss the adequacy of the broadly used single-mode cavity approximation to describe such regimes. We have demonstrated that, in the non-perturbative light–matter coupling regimes, the single-mode models become unphysical, allowing for superluminal signalling [2]. Moreover, considering the specific example of the quantum Rabi model, we show that the multi-mode description of the electromagnetic field, necessary to account for light propagation at finite speed, yields physical observables that differ radically from their single-mode counterparts already for moderate values of the coupling. Our multimode analysis also reveals phenomena of fundamental interest on the dynamics of the intracavity electric field, where a free photonic wavefront and a bound state of virtual photons are shown to coexist.

References

Forn-Díaz, P., Lamata, L., Rico, E., Kono, J., & Solano, E. (2018). arXiv:1804.09275.

Sánchez Muñoz, C., Nori, F., and De Liberato, S., Nature Communications (2018) 9:1924.

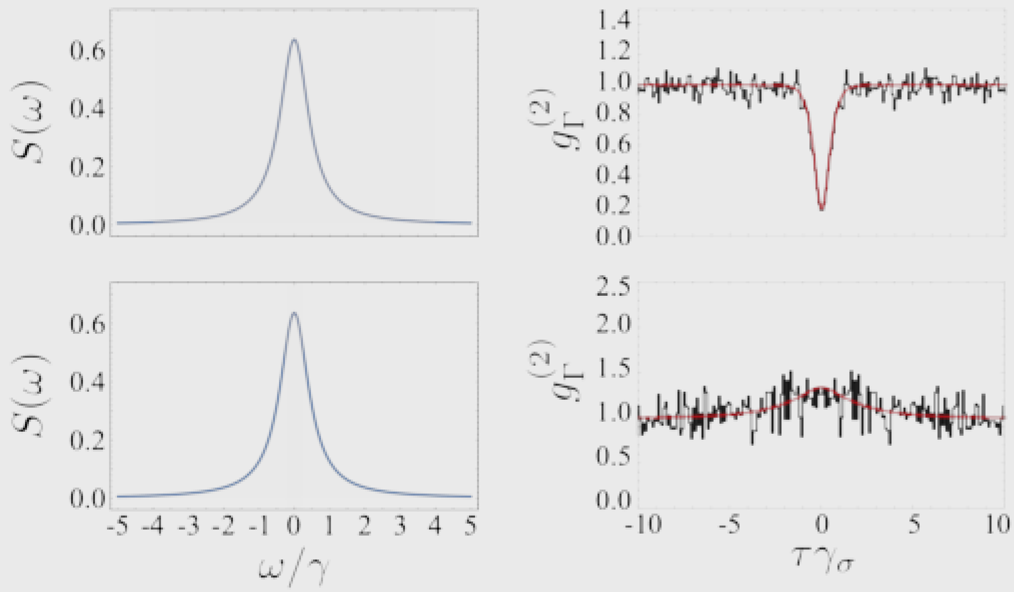
It is our great pleasure to announce the XXV International Summer School "Nicolás Cabrera". This series of summer schools, organized by the Instituto Nicolás Cabrera at the Universidad Autónoma de Madrid and financed by the Fundación BBVA, deals with current topics in Materials Science since 1994. Next year, it will focus on "Manipulating Light and Matter at the Nanoscale", and will be held from the 10th to the 14th of September 2018 in Miraflores de la Sierra, Spain (close to Madrid).

This international school aims to provide a broad introduction to current trends in light-matter interactions at the nanoscale to students and young postdocs. A list of confirmed keynote and invited speakers, as well as other details and information, can be found at INC Summer School 2018.

The School will consist of lectures, discussions, and poster sessions, and will last from the morning of Monday, Sep 10, until around noon on Friday, Sep 14. It will include a half-day excursion to a landmark and a traditional dinner in the vicinity of Madrid.

Note that registration is already open. The fee (400€) covers accommodation, meals, and coffee breaks, as well as the school trip and dinner. A limited number of scholarships to waive the registration fee will be available.
If you have any questions, please, do not hesitate to contact us at school@nicolascabrera.es.

Frequency-resolved Monte Carlo



Photon correlations of the light emitted by a two-level system change as the resolution in the energy of the photons is increased. The correlations obtained through our Monte Carlo technique (shown in black) match perfectly with the prediction from the theory frequency-resolved correlations (shown in red).

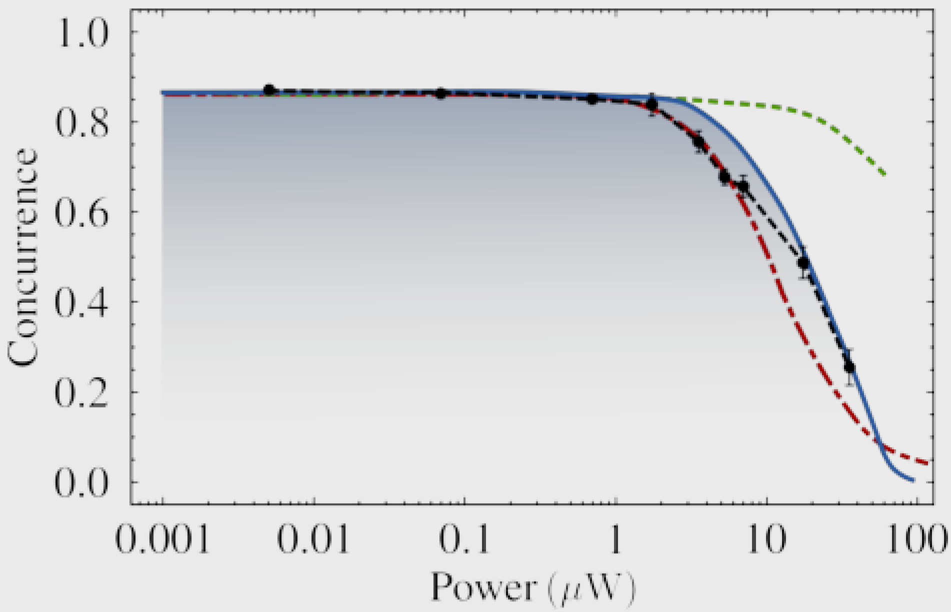
Article: published in Scientific Reports by Juan Camilo López Carreño, Elena del Valle, members of the Department of Theoretical Condensed Matter Physics.

The Monte Carlo method, devised by Ulam in the 1940s, relies on random sampling to estimate the value of variables in problems that are difficult to tackle analytically. In particular, the method has proven specially helpful to simulate stochastic problems, such as the trajectories of a random walker (which has application across all sciences) or the neutron diffusion.
In the late 80s and early 90s, Zoller, Marte & Walls and Dalibard, Castin & Molmer adapted the Monte Carlo method to the formalism of the quantum master equations, in which the stochastic processes, such as spontaneous emission, are described as Lindblad terms. In this paper [Sci. Rep. 8, 6975 (2018)], we extend the range of

applicability of the Monte Carlo method, by adapting it to the Cascaded formalism of Quantum Optics, which enables us to simulate the emission of photons of known energies.

We apply the technique to the photon emission from a two-level systems driven by either an incoherent or a coherent pump. Doing a statistical analysis of the photon-emission streams, we find a perfect agreement with the theory of frequency-resolved correlations, which confirms the correctness of our technique. In particular, using a coherent driving in the Mollow triplet regime, we demonstrate directly the manifestation of the so-called “leapfrog processes” whereby the two-photon emission rate is increased. [Full article]

First Observation of the Quantized Exciton-polariton Field and Effect of Interactions on a Single Polariton



Article: published in Science Advances by Juan Camilo López Carreño, Blanca Silva, Elena del Valle, members of the Department of Theoretical Condensed Matter Physics.

In 1982 Richard Feynmann envisioned the Quantum Computer, and although it has received the attention of two generations of Quantum Physicist around the world, its realization is still in a gestational stage. Many efforts have been devoted to demonstrate both the suitability and the miniaturization potential of diverse platforms to encode and manipulate Quantum Information. On these counts, photons would be the ideal carriers if it was not for their lack of interactions, without which the logical gates (the building blocks of a computer) cannot be implemented.

Creation of a quantum polariton.

Exciton-polaritons, hybrid particles that arise from the strong coupling between a photon and an exciton (an electron-hole pair), are a natural substitute of photons, as they inherit an interactive character from the excitons while retaining the lightweight and coherence from the photons. In a recent paper [Sci. Adv. 4, eaao6814 (2018)], by exciting the field of exciton-polaritons (from here on simply “polaritons”) with one of the photons from a pair of polarization-entangled photons, we observed for the first time a genuine quantum state (i.e., one that cannot be described as a convex mixture of Gaussian states) of the polariton field. A measurement of the classical CHSH inequality between the light emitted by the polariton and the other photon from the entangled pair shows that the quantum correlations are maintained, even after one of the photons became a polariton. Furthermore, by letting the single polariton cohabit with a condensate of polaritons, we were able to alter the phase of the single-polariton, as observed through an apparent loss of entanglement. This shows that polaritons could be fully manipulated at the quantum level in the near future and become the qubits of a quantum computer. [Full article]