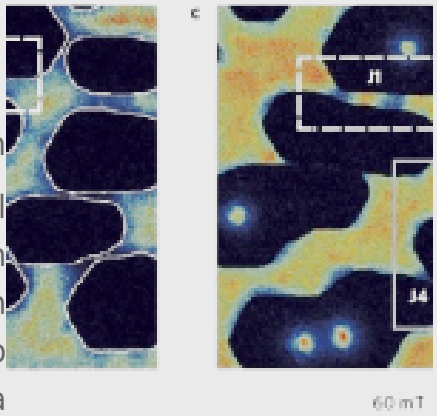
Direct Observation of Josephson Vortex Cores - published in Nature Physics

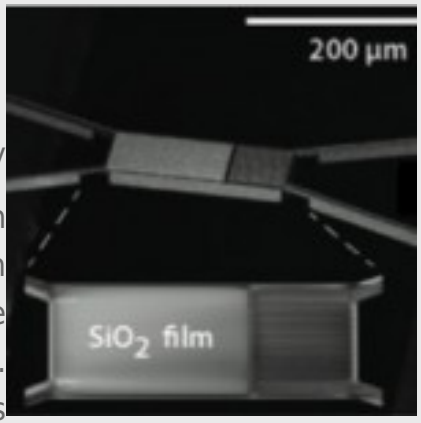


When a normal metal is brought in contact with a superconductor, Cooper pairs may leak into the metal inducing genuine superconducting properties in it, an effect generically referred to as proximity effect. In particular, if a metal is sandwiched between two superconductors, it can sustain the flow of a dissipationless or Josephson current. When a magnetic is applied to a Josephson junction, the Josephson currents oscillate along the interface splitting up the junction into regions that enclose no net current, which are known as Josepshon vortices. Contrary to Abrikosov vortices in type II superconductors, the Josephson vortices are supposed to lack of a normal core (where the superconductivity is completely suppressed). However, it was predicted by J. C. Cuevas and F. S. Bergeret in 2007 that if the weak link is made of a diffusive metal, the junctions can sustain Josephson vortices with true vortex cores inside the metal. Now, in collaboration with the Group of Spectroscopy of Novel Quantum States (Institut des Nanosciences de Paris and Université Pierre et Marie Curie), we report the first direct observation of these proximity Josephson vortices. In our case, the junctions are made of superconducting Pb nanoislands weakly linked by a normal (atomically thin) wetting layer of Pb, which is not superconducting. The Josephson vortices were imaged by means of a low-temperature scanning tunneling microscope, and they were revealed by the spatial modulation of the local density of state in the wetting layer induced by the magnetic field. Our results strongly suggest that it should be possible to induce these proximity vortices in novel quantum devices by purely electrical means. Moreover, we may anticipate the observation of these vortices in other superconducting weak links made of low-dimensional materials such a graphene.

Reference:

Direct observation of Josephson vortex cores. D. Roditchev, C. Brun, L. Serrier-Garcia, J. C. Cuevas, V. H. L. Bessa, M. V. Milosevic, F. Debontridder, V. Stolyarov, T. Cren. Nature Physics, in press (2015).

Enhancement of Near-field Radiative Heat Transfer Using Polar dielectric Thin Films - published in Nature Nanotechnology

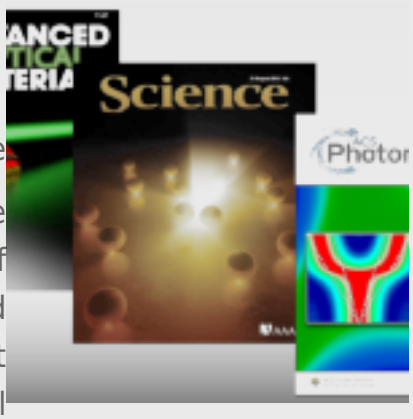


Thermal radiation plays a major role in energy conversion, thermal management, and data storage. In recent years, several experiments on thermal radiation between bulk materials have demonstrated that radiative heat transfer can be greatly enhanced in nanoscale gaps. However, it was not clear whether such enhancements could be obtained with nanoscale films thinner than the penetration depth of radiation. In this work, our colleagues of the University of Michigan (the groups of Pramod Reddy and Edgar Meyhofer) have conducted near-field radiation experiments using a novel ultrasensitive calorimeter that demonstrate enhancements of several orders of magnitude in radiative heat transfer, even for ultra thin dielectric films (50 nm), at spatial separations comparable to or smaller than the film thickness. Researchers from IFIMAC (V. Fernández-Hurtado, J. Feist, F. J. García-Vidal and J. C. Cuevas) have explained these striking results making use of the theory of fluctuational electrodynamics. In particular, we have showed that the near field radiative heat transfer in polar dielectric thin films is determined by the excitation of cavity surface phonon polaritons. These surface electromagnetic modes have characteristic penetration depths that are of the order of the gap separating the receiver from the emitter. In practice, this implies that the entire near field thermal radiation emitted by a polar material comes from its surface. Thus, the thermal emission of a polar thin film is independent of its thickness, as long as the gap between materials remains smaller than the film thickness. Our findings have important implications to a variety of future energy conversion and heat transfer nanotechnologies.

Reference:

Enhancement of near-field radiative heat transfer in polar dielectric thin films. B. Song, Y. Ganjeh, S. Sadat, D. Thompson, A. Fiorino, V. Fernández-Hurtado, J. Feist, F.J. Garcia-Vidal, J.C. Cuevas, Pramod Reddy, Edgar Meyhofer. Publicado en Nature Nanotechnology (2015). doi:10.1038/nnano.2015.6

PhD Studentship Funded by the EU-FP7 Marie Curie Career Integration Grants – Closed



A 4-year PhD studentship funded by the EU-FP7 Marie Curie Career Integration Grants scheme is available. The research work will focused on the theoretical description of surface-plasmon-assisted phenomena at the nano- and subnano-metric scales. The ultimate objective of the project is to devise theoretical tools able to describe the optical properties of macroscopic-sized systems where the quantum character of light and matter cannot be neglected.

Project Information

Funding agency: EU FP7 Marie Curie Career Integration Grants Scheme

Project acronym: MESOPLAS

Principal investigator: Antonio I. Fernández Domínguez

Deadline: May 1st, 2015

Contact: Interested applicants must contact by e-mail directly A. I. Fernández-Domínguez at a.fernandez-dominguez(at)uam.es

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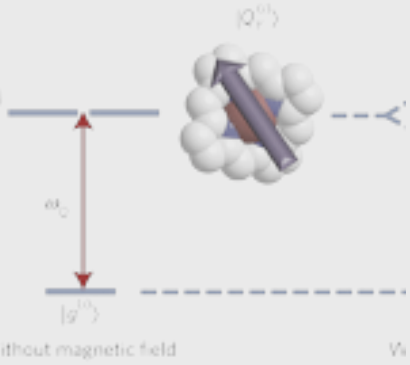
Spectroscopy and Topological Phases for Organic Excitons

Date: Monday 16th March, 2015, 12h00

Place: Department of Condensed Matter Physics, Facultad Ciencias, Module 3, Seminar Room (5th Floor).

Speaker: Joel Yuen-Zhou, Center for Excitonics, Massachusetts Institute of Technology, USA.



Abstract:

The understanding and control of energy flow at the nanoscale via exciton dynamics in organic materials is of fundamental chemical and physical interest, but is also technologically relevant for the design of novel photovoltaic materials. In the first part of my talk, I will explain some of our work designing spectroscopic protocols to understand exciton dynamics under coherent illumination via ultrafast Quantum

Process Tomography (QPT), a technique which retrieves the time evolution of the quantum state of the excitons via nonlinear spectroscopy (1,2). As an application, I will describe the first ultrafast QPT experiment carried out with the Nelson and Bawendi groups at MIT on a nanotubular J-aggregate system at room temperature.
In the second part, I will describe current work (3,4) designing topologically nontrivial phases that robustly and selectively move excitons in particular spatial directions of a molecular crystal, simulating solid state "topologically protected" phenomena like the Quantum Hall Effect, which are robust against material imperfections and static disorder.
References:

J. Yuen-Zhou, Jacob J. Krich, Masoud Mohseni, and A. Aspuru-Guzik, Quantum state and process tomography of energy transfer systems via ultrafast spectroscopy, Proc. Nat. Acad. Sci. USA. 108, 43, 17615 (2011).

J. Yuen-Zhou, D. Arias, D. Eisele, J. J. Krich, C. Steiner, K. A. Nelson, and A. Aspuru. Guzik, Coherent exciton dynamics in supramolecular light-harvesting nanotubes revealed by ultrafast quantum process tomography, ACS Nano 8 (6) 5527 (2014).

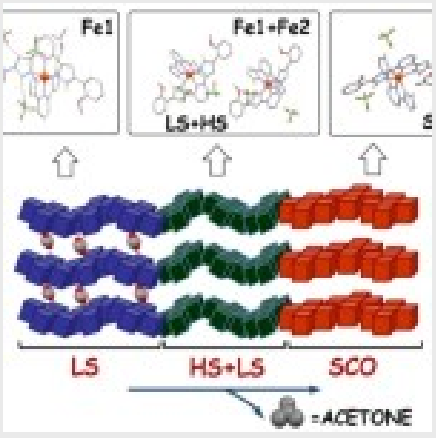
J. Yuen-Zhou, S. Saikin, N. Yao, and A. Aspuru-Guzik, Topologically protected excitons in porphyrin thin films, Nature Materials 13, 1026 (2014).

J. Yuen-Zhou, S. Saikin, T. Zhu, V. Bulovic, M. Baldo, Topological plexcitons with organic molecular crystals, in preparation, (2015).

More information on IFIMAC Website

Crystallographic Transitions Coupled to Spin Crossover in Molecular Complexes

Date: Friday 13 February, 12h00, 2015.
Place: Department of Theoretical Condensed Matter Physics, Facultad Ciencias, Module 5, Seminar Room (5th Floor).
Speaker: Guillem Aromí, Group of Magnetism and Functional Molecules (GMMF) Universitat de Barcelona, Barcelona, Spain.



Abstract:

Spin crossover (SCO) is a switch of spin states that may be seen in some octahedral d4 to d7 transition metals, triggered by external stimuli, also involving

changes to other properties. In the case of Fe(II), it causes dramatic variations in bond distances to the metal and other parameters. Thus, when the spin active species lay connected by intermolecular interactions within a crystal, long range effects may induce cooperativity to this transition and often, a hysteresis loop, which is the signature of bistability. The intimate relation between structure and spin, very often results in intricate coupled crystallographic/magnetic transitions during SCO. In order to unveil the details of such coupling, we have designed ligands for the preparation of Fe(II) SCO complexes with dense arrays of intermolecular interactions [1-4]. This work has uncovered intriguing correlations spin state / crystallographic order [1,3] and in particular, reversible solvent desorption processes involving spin transitions and drastic crystallographic changes, as shown by single crystal X-ray crystallography.[5] Remarkably, these transitions occur through an intermediate spin and crystallographically ordered phase, also fully characterized. Astonishingly, several combinations of these three phases have been demonstrated by single crystal X-ray diffraction to coexist within one single crystal.

References:

Craig G. A., Costa J. S., Roubeau O., Teat S. J., Aromí G. Chem. Eur. J., 17, (2011) 3120 – 3127.

Craig G. A., Costa J. S., Roubeau O., Teat S. J., Aromí G. Chem. Eur. J., 18, (2012), 11703 – 11715.

Craig G. A., Costa J. S., Roubeau O., Teat S. J., Yufit, D.S., Howard J.A.K., Aromí G., Inorg. Chem, 52, (2013), 7203−7209.

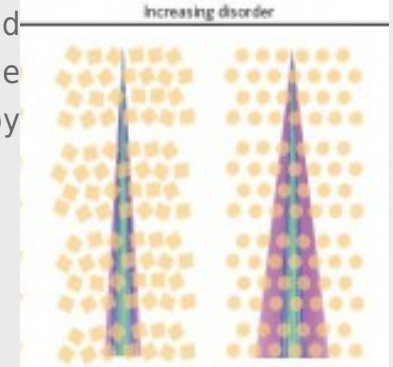
Craig G. A., Costa J. S., Roubeau O., Teat S. J., Howard J.A.K., Lopes M., Molnár G., Bousseksou A., Aromí G., 43 (2014) Dalton Trans. 729.

Costa J. S., Rodríguez-Jiménez S., Craig G. A., Barth, B., Beavers C. M., Teat S. J., Aromí G. J. Am. Chem. Soc. 136 (2014), 3869−3874.

More information on IFIMAC Website

Disorder Sets Light Straight - published in Nature Physics News and Views

In a recent Nature Physics News & Views article entitled 'Disorder sets Light straight' Jorge Bravo-Abad discusses the fascinating discovery of light supercollimation assisted by transverse Anderson localization.



Abstract:

Non-diffractive light propagation based on perfectly periodic photonic structures has one fundamental drawback: it only works within a narrow frequency bandwidth, which makes supercollimation effects very sensitive to frequency variations of the propagating beam. Hsieh et al. now demonstrate that disorder can become an unexpected ally for tackling this problem. At first sight the approach of Hsieh et al. could seem counterintuitive. It is well known that structural disorder is detrimental to any optical functionality of a periodic photonic structure. But instead of battling disorder, they discovered a fundamental way to leverage it. As they report in Nature Physics, Pin-Chun Hsieh and colleagues demonstrate how disorder can enhance the collimation of light through Anderson localization – a universal wave phenomenon introduced almost six decades ago in the context of electronic transport in disordered solids.

Material Design and Strongly Correlated Electron Systems

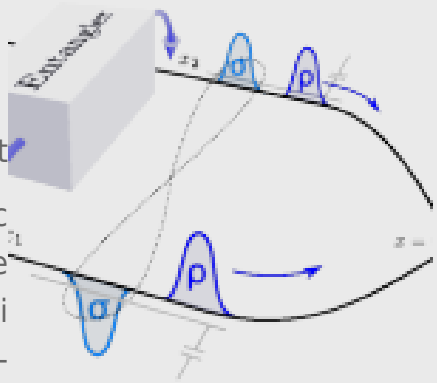
INC COLLOQUIUM – OFFICIAL ANNOUNCEMENT

Title: Material Design and Strongly Correlated Electron Systems
When: Friday, 16th of January, 2015 at 12h30
Where: Sala de conferencias módulo 00, Facultad de Ciencias.
Speaker: Gabriel Kotliar, Rutgers University
ABSTRACT:

Our understanding of simple solids, is firmly grounded on the Fermi liquid

concept and powerful computational techniques built around the density functional theory. These ideas form the basis of our “standard model” of solid state physics and have provided us with an accurate description of many materials of great technological significance.
Correlated electron systems are materials for which the the standard model of solid state physics fails dramatically. The best known example being the copper oxide high temperature superconductors.
Correlated electron materials continue to be discovered accidentally and surprise us with their exceptional physical properties and their potential for new applications. The most recent example is provided by the iron arsenide based high temperature superconductors.
From a theoretical perspective describing strongly correlated electron systems pose one of the most difficult non-perturbative challenges in physics. In this colloquium I will give an elementary introduction to the field of strongly correlated electron materials and Dynamical Mean Field Theory (DMFT) a non perturbative method which provides a zeroth order picture of the strong correlation phenomena in close analogy with the Weiss mean field theory in statistical mechanics. Applications materials containing f and d electrons will be presented to show how the anomalous properties of correlated materials emerge from their atomic constituents.
I will conclude with an outlook of the challenges ahead and the perspectives for a rational material design.

Detection of Spin Entanglement via Spin-Charge Separation in Crossed Tomonaga-Luttinger Liquids - published in Physical Review Letters



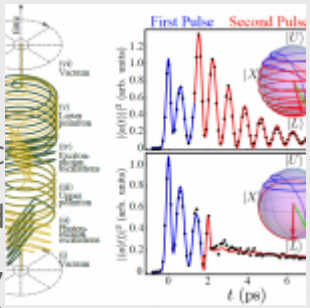
In this work we demonstrate that simple dc current measurements can reveal the presence of electronic entanglement between two interacting nanowires. The effect is based on spin-charge separation, a non-Fermi liquid property characteristic of interacting one-dimensional systems.
Abstract:
We investigate tunneling between two spinful Tomonaga-Luttinger liquids (TLLs) realized, e.g., as two crossed nanowires or quantum Hall edge states. When injecting into each TLL one electron of opposite spin, the dc current measured after the crossing differs for singlet, triplet, or product states. This is a striking new non-Fermi liquid

feature because the (mean) current in a noninteracting beam splitter is insensitive to spin entanglement. It can be understood in terms of collective excitations subject to spin-charge separation. This behavior may offer an easier alternative to traditional entanglement detection schemes based on current noise, which we show to be suppressed by the interactions.

Reference:

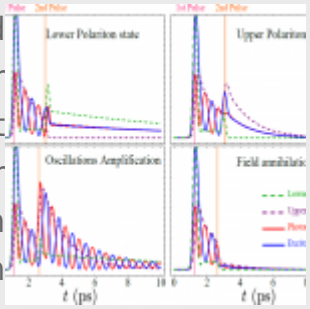
Detection of Spin Entanglement via Spin-Charge Separation in Crossed Tomonaga-Luttinger Liquids, Phys. Rev. Lett. 113, 266401 – Published 23 December 2014.

Ultrafast Control and Rabi Oscillations of Polaritons - published in Physical Review Letters



The full control of Rabi oscillations in polaritonic semiconductor microcavities has been demonstrated and theorized by researchers of the department (D. Colas, J. P. Restrepo Cuartas, J. C. López Carreño, E. del Valle and F. P. Laussy) in collaboration with the group of Daniele Sanvitto (Lecce, Italie). These results were published in Physical Review Letters.

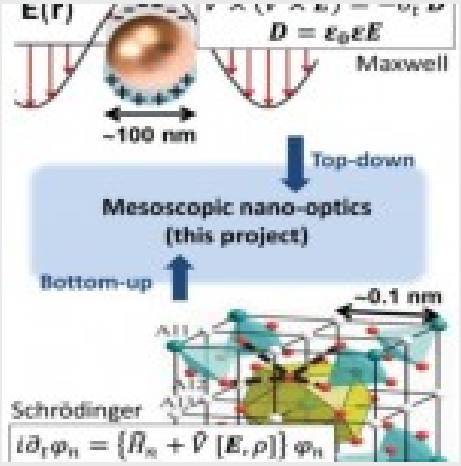
Abstract:



We report the experimental observation and control of space and time-resolved light-matter Rabi oscillations in a microcavity. Our setup precision and the system coherence are so high that coherent control can be implemented with amplification or switching off of the oscillations and even erasing of the polariton density by optical pulses. The data are reproduced by a quantum optical model with excellent accuracy, providing new insights on the key components that rule the polariton dynamics.

MESOPLAS - FP7 Marie Curie Career Integration Grants

Funding agency: FP7 Marie Curie Career Integration Grants
Identifier: PCIG14-GA-2013-630996 MESOPLAS
Duration: February 2015 – January 2019
Principal Investigator: A. I. Fernandez-Dominguez



Description:

The boost experienced by nanophotonics research during the past decade has been driven by the ability of surface plasmons to collect and concentrate light into deeply sub-wavelength volumes. The hybrid nature of surface plasmons (which emerge from the coupling of photons to the collective oscillations of conduction electrons in metals) has allowed an unprecedented control of light at the nanoscale, a regime inaccessible to standard photonic technology. This scientific success has been possible due to two factors: the high precision of modern nanofabrication and characterization techniques, and the extraordinary predictive value of classical electrodynamics.
However, the miniaturization trend in experimental nano-optics is currently approaching dimensions comparable to the typical Coulomb screening length in noble metals (of the order of a few angstroms). A theoretical challenge arises in this spatial range for two reasons. On the one hand, at this sub-nanometre regime, macroscopic electromagnetism breaks down due to the emergence of quantum effects such as spatial non-locality. On the other hand, the enormous complexity of the full quantum numerical schemes available to describe the electron-ion dynamics in metals restricts their applicability to systems involving only a few hundreds of electrons.
The objective of this project is to fill the gap between Maxwell's equations and first principle condensed matter theory methods. It aims to devise a mesoscopic platform able to treat accurately and efficiently the interaction between light and matter in nanodevices which, presenting angstrom-sized geometric features, contain millions of electrons. This is a prominent fundamental problem with significant technological implications. The further development of nanophotonic technology requires a complete and unified picture of the physical mechanisms behind its performance. The ultimate goal of this proposal is providing the theoretical framework for this purpose.