

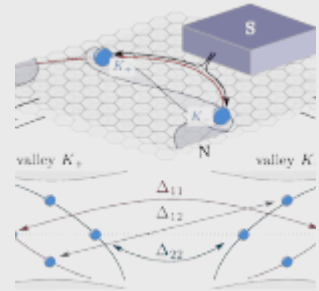
## Transport Through Topological Confined States of Matter

Title: Transport Through Topological Confined States of Matter.

When: Monday, January 30, (2017), 12:00.

Place: Departamento de Física Teórica de la Materia Condensada, Facultad Ciencias, Module 5, Seminar Room (5th Floor).

Speaker: Patrik Recher, Technische Universität Braunschweig Institut für Mathematische Physik, Braunschweig, Germany.



In my talk, I will introduce transport calculations through topologically confined states of matter. In graphene and silicene, valley chiral states can be created by a mass domain wall that is tunable by an applied voltage. Contacting these valley chiral states with superconductors, I will discuss novel ways to split spin-entangled Cooper pairs using the valley degree of freedom [1] and to tune the Josephson effect from a  $2\pi$  to  $4\pi$  phase relation when in addition spin-orbit coupling is present. Further topological confined states of interest are Majorana bound states (MBS) in topological superconductors. I will show that transport through networks of such MBS can be conveniently described using full counting statistics and that unique signatures of MBS are seen in Fano resonances in a setup where the MBS are coupled to a normal metal lead and to a quantum dot.

References

A. Schroer, P.G. Silvestrov, and P. Recher, Phys. Rev. B 92, 241404(R) (2015).

[More information on IFIMAC Website](#)

---

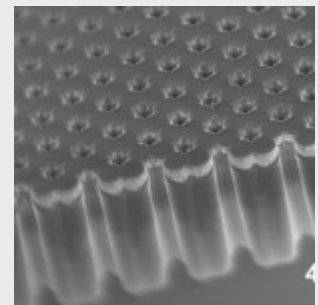
## Polaritons in Lattices: A Nonlinear Photonic Emulator of Graphene

Title: Polaritons in Lattices: A Nonlinear Photonic Emulator of Graphene.

When: Thursday, 07 July (2016), 16.00-17.00 h.

Place: Departamento de Física Teórica de la Materia Condensada, Facultad Ciencias, Module 5, Seminar Room (5th Floor).

Speaker: Alberto Amo, Centre de Nanosciences et de Nanotechnologies, CNRS, Univ. Paris-Sud, Université Paris-Saclay, France.



# E

xciton polaritons are quasi-particles arising from the strong coupling of quantum well excitons and cavity photons in semiconductor microcavities.

Thanks to their mixed light-matter nature, polaritons present unique nonlinear properties while, simultaneously, allowing the design of the photonic potential landscape. The direct visualisation of polariton eigenfunctions in luminescence experiments, makes microcavities an extraordinary photonic platform to emulate 1D and 2D nonlinear Hamiltonians.

In this way, polaritons allow transposing to the photonic world some of the properties of electrons in solid state systems, and to engineer Hamiltonians with novel transport and nonlinear properties.

In this presentation we will show striking nonlinear effects in two coupled micropillars which can be described by the nonlinear Bose-Hubbard dimer. We will then address the physics of a honeycomb lattice of coupled micropillars [1]. Its band structure emulates for photons the  $\pi$  and  $\pi^*$  bands of graphene [2, 3]. In addition, our system permits exploring orbital degrees of freedom, inaccessible in actual graphene, which give rise to flat bands and novel kind of edge states.

Our system presents interesting perspectives in view of studying nonlinear excitations in engineered photonic Hamiltonians owing to polariton-polariton interactions [4].

## References

S. R. K. Rodriguez et al., Interaction-induced hopping phase in driven-dissipative coupled photonic microcavities. *Nat. Commun.* 7, 11887 (2016).

T. Jacqmin et al., Direct Observation of Dirac Cones and a Flatband in a Honeycomb Lattice for Polaritons. *Phys. Rev. Lett.* 112, 116402 (2014).

M. Milićević et al., Edge states in polariton honeycomb lattices. *2D Mater.* 2, 034012 (2015).

F. Baboux et al., Bosonic Condensation and Disorder-Induced Localization in a Flat Band. *Phys. Rev. Lett.* 116, 066402 (2016).

[More information on IFIMAC Website](#)

---

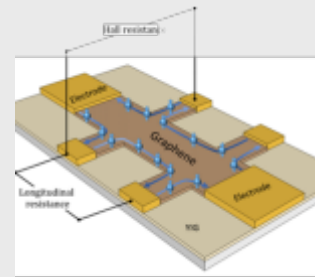
[Spin Pumping And Quantum Anomalous Hall Effect In 2D-based Materials](#)

Title: Spin Pumping And Quantum Anomalous Hall Effect In 2D-based Materials

When: Monday, 25 April (2016), 12:00h

Place: Departamento de Física Teórica de la Materia Condensada, Facultad Ciencias, Module 5, Seminar Room (5th Floor).

Speaker: Mario Amado, Department of Materials Science and Metallurgy, University of Cambridge, UK.



The recent discovery of the quantum anomalous Hall effect (QAHE) in magnetically doped topological insulators cooled below the millikelvin regime represents a breakthrough in the field of spintronics(1). Theoretically, the QAHE should occur in graphene proximity-coupled to a ferromagnetic insulator(2) but with the promise of much higher operating temperatures for practical applications. Hints of proximity-induced magnetism in graphene coupled to yttrium iron garnet (YIG) films have been reported(3), although the QAHE remains unobserved; the lack of a fully developed plateau in graphene/YIG devices can be attributed to poor interfacial coupling and therefore a dramatically reduced magnetic proximity effect.

Here we report the deposition and characterisation of epitaxial thin-films of YIG on lattice-matched gadolinium gallium garnet substrates by pulsed laser deposition. Pristine exfoliated graphene flakes transferred mechanically onto the YIG are reported alongside results that correlate the effects of YIG morphology on the electronic and crystal properties of graphene by electrical (low temperature magnetoresistance measurements in Hall-bar-like configuration) and optical (Raman) means.

#### References

C.Z. Chang et al., Science 340, 167 (2013) and C.Z. Chang et al., Nature Materials 14, 473 (2015).

C. L. Kane and E. J. Mele, Phys. Rev. Lett. 95, 226801 (2005).

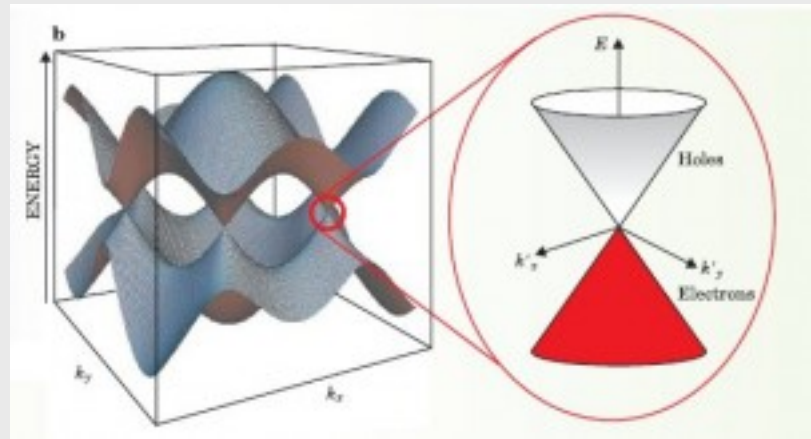
Z. Wang et al., Phys. Rev. Lett. 114, 016603 (2015).

[More information on IFIMAC Website](#)

---

[Strained Graphene Revisited](#)

Date: Friday, 24th January 2014.



Time: 12:00h

Place: Departamento de Física Teórica de la Materia Condensada, Facultad Ciencias, Módulo 5 , Aula de Seminarios (5ª Planta).

María A. H. Vozmediano (Instituto de Ciencia de Materiales de Madrid-CSIC).

ABSTRACT:

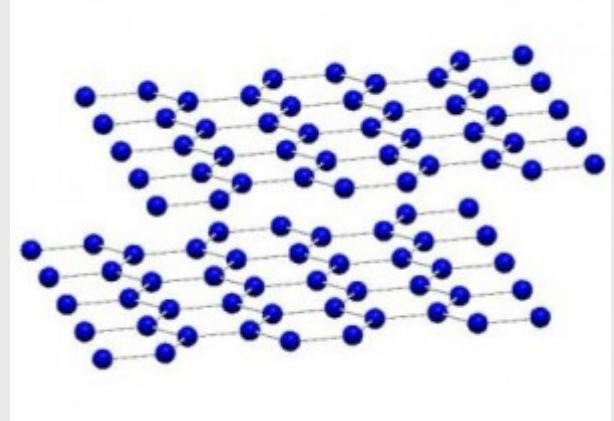
**W**e investigate some apparent discrepancies between two different models for curved graphene: the one based on tight-binding and elasticity theory, and the covariant approach based on quantum field theory in curved space. We demonstrate that strained or corrugated samples will have a space-dependent Fermi velocity in either approach that can affect the interpretation of local probe experiments in graphene. We also generalize the tight-binding approach to general inhomogeneous strain and find an extra vector field proportional to the derivative of the strain tensor that has the same form as the one obtained in the covariant approach. Finally we show that extra terms arise in the continuum limit of the tight-binding Hamiltonian due to frame effects which cannot be accounted for by changes in the hopping parameters due to lattice deformations, encoded in the parameter.

[More information on IFIMAC Website](#)

---

[Ising Phase in AA Stacked Bilayer Graphene](#)

Date: Friday, 29nd November (2013).



Time: 12:00h

Place: Departamento de Física de la Materia Condensada, Facultad Ciencias, Módulo 3 ,  
Aula de Seminarios (5ª Planta)

Prof. Luis Brey (Instituto de Ciencia de Materiales de Madrid (CSIC), SPAIN).

ABSTRACT:

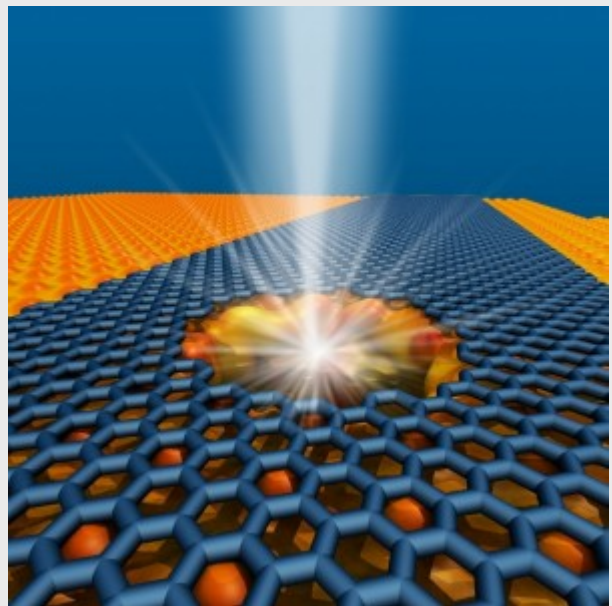
**R**ecently it has become possible to fabricate AA-stacked bilayer graphene in real samples. AA-stacked bilayer graphene supports Fermi circles in its bonding and antibonding bands, which coincide exactly, leading to symmetry breaking in the presence of electron-electron interactions. This system bears a close resemblance to biased, double layer graphene (in which a strong barrier separates the two layers), which is believed to ideally support spontaneous exciton condensation due to perfect nesting of the Fermi surfaces. Layer bonding and anti-bonding states of the AA system play the roles of layer states of the double layer system, and in the former case the system has only Ising symmetry, whereas the latter has a U(1) symmetry. In this presentation we analyze the possibility that electron-electron interactions break the Ising symmetry and open a gap in the energy spectrum. We find that, in the mean field approximation, the ground state has a charge density wave character, with the charge modulation of each layer out of phase. We calculate the gap and the mean field critical temperature as a function of the strength of the Coulomb interaction, taking screening into account self-consistently with the calculation of the gap. We also analyze the transition between ordered and thermally disordered phases based on a continuum model, and find that the transition is controlled by an effective U(1) stiffness. We argue that in the limit of zero layer separation, for which the full U(1) symmetry of the Hamiltonian is restored, the Ising transition continuously goes into a Kosterlitz-Thouless transition.

[More information on IFIMAC Website](#)

---

## Transport in Atomically Resolved Graphene Nanoribbons

*Date: Friday, 22nd November (2013).*



*Time: 12:00h*

*Place: Departamento de Física de la Materia Condensada, Facultad Ciencias, Módulo 3 ,  
Aula de Seminarios (5ª Planta)*

*Prof. A.T. Charlie Johnson (Department of Physics & Astronomy; Director Nano/Bio  
Interface Center, University of Pennsylvania, USA).*

ABSTRACT:

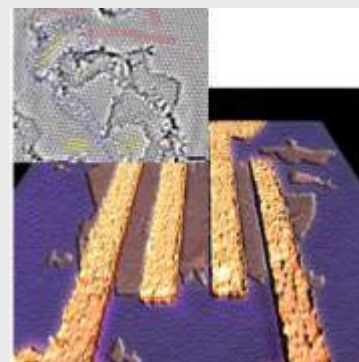
**G**raphene has attracted intense research focus as an emerging material for high performance electronics components due to its superior intrinsic carrier mobility, thermal conductivity, and quasi-ballistic transport at room temperature. The Johnson group has advanced the synthesis of high quality large-area graphene by atmospheric pressure chemical vapor deposition, which has enabled experiments that would be difficult if not impossible to perform with exfoliated graphene material. Examples to be discussed include translocation of DNA through graphene nanopores and synthesis of single-crystal monolayer heterostructures of graphene and hexagonal boron nitride. Finally I will focus on recent experiments where graphene nanoribbons have been fabricated, structurally characterized with atomic resolution, and electrically probed, all in situ in an aberration-corrected transmission electron microscope.

[More information on IFIMAC Website](#)

---

## The influence of defects in the electrical transport properties of metalorganic nanoribbons and in the mechanical properties of suspended graphene flakes

Wednesday, 23th January 2013. 12:00-13:00



Julio Gómez Herrero

(Departamento de Física de la Materia Condensada, UAM)

ABSTRACT:

In this talk I will briefly discuss two different topics related with the influence of defects in nanoscale systems [1,2]. The first one is related to the electrical transport properties of MMX nanoribbons. MMX compounds can be seen as one dimensional metal organic polymers that include a bimetal unit (MM can be Mo, Pt,...) and a linker that is usually a halogen. In our case we will focus on a MMX based on platinum and iodine as the linker. These compounds present a significant electrical conductivity that has been traditionally studied in macroscopic crystals. In this talk I will describe the synthesis [3] and electrical transport properties [4] of MMX nanoribbons, the influence of defects [5] in their conductivity and the transition between the nanoscale and macroscale regime. The second topic deals with the influence of induced defects in the mechanical properties of suspended graphene flakes. Using and atomic force microscopy we indent graphene flakes with different densities of defects. The experiments show an extreme drop of the breaking force with the irradiation dose and an unexpected increase of the Young modulus of the flake for low defect densities.

- [1] Gomez-Navarro, C., P.J. De Pablo, J. Gomez-Herrero, B. Biel, F.J. Garcia-Vidal, A. Rubio, and F. Flores, *Tuning the conductance of single-walled carbon nanotubes by ion irradiation in the Anderson localization regime*. Nature Materials, 2005. 4(7): p. 534-539.
- [2] Sundqvist, P., F.J. Garcia-Vidal, F. Flores, M. Moreno-Moreno, C. Gomez-Navarro, J.S. Bunch, and J. Gomez-Herrero, *Voltage and length-dependent phase diagram of the electronic transport in carbon nanotubes*. Nano Letters, 2007. 7(9): p. 2568-2573
- [3] Welte, L., U. Garcia-Couceiro, O. Castillo, D. Olea, C. Polop, A. Guijarro, A. Luque, J.M. Gomez-Rodriguez, J. Gomez-Herrero, and F. Zamora, *Organization of Coordination*

*Polymers on Surfaces by Direct Sublimation*. *Advanced Materials*, 2009. 21(20): p. 2025-2028.

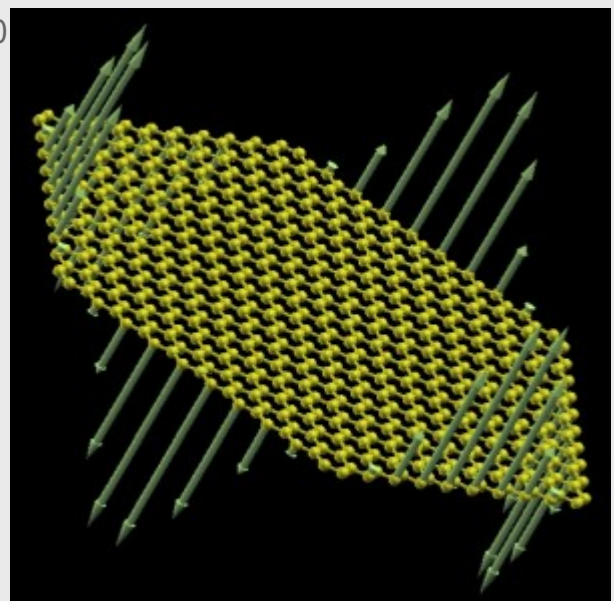
[4] Welte, L., A. Calzolari, R. Di Felice, F. Zamora, and J. Gomez-Herrero, *Highly conductive self-assembled nanoribbons of coordination polymers*. *Nature Nanotechnology*, 2010. 5(2): p. 110-115.

[5] Cristina Hermosa *et al.*, *Intrinsic electrical conductivity of nanostructured metal-organic polymer chains*. Submitted.

---

## Periodically nanostructured graphene

Wednesday, 12th December 2012. 12:00-13:00



*Amadeo L. Vázquez de Parga*

*(Departamento de Física de la Materia Condensada, UAM and IMDEA-Nanociencia)*

### ABSTRACT:

Ultra perfect graphene monolayers, islands and ribbons can be epitaxially grown on different single crystal metal surfaces under Ultra High Vacuum conditions. These graphene layers are spontaneously nanostructured in a periodic array of ripples by the moiré patterns caused by the difference in lattice parameter with the different substrates.

We characterize its perfection at the atomic scale by means of Scanning Tunnelling Microscopy (STM) and determine its electronic structure in the real space by local tunnelling spectroscopy (STS). In-situ STM imaging of graphene monolayers on Ru(0001) reveals periodic corrugations with  $12 \times 12$  periodicity. The apparent corrugation depends strongly on the bias voltage and can even be inverted above +2.6 V, revealing that, in addition to the geometric corrugation, a much stronger electronic corrugation exists. Moiré patterns have been observed with STM on different systems and their interpretation, in some cases, is not straightforward. The main reason is that



in STM images the geometric corrugation and the electronic structure are entangled [1, 2]. Graphene grown on Ru(0001) presents periodic variations in the electronic structure induced by the chemical interaction between the carbon atoms and the ruthenium ones. By means of STS we observe inhomogeneities in the charge distribution along the moiré unit cell [3]: The surface potential landscape can be explored with nanometer resolution measuring the Field Emission Resonances (FERs). For graphene on Ru(0001) we have found differences in the value of the surface potential depending on the position on the moiré pattern. The energy position of the first FER presents strong spatial variations due to the hybridization with a Ru(0001) surface resonance [4]. We have been using this periodically nanostructure graphene to growth electron acceptor molecules like 7,7',8,8'-tetracyano-*p*-quinodimethane (TCNQ). The graphene overlayer electronically decouples TCNQ molecules from the Ru(0001). The energy position and spatial distribution of the molecular frontier orbitals for a single molecule are measured by STS maps at 4.6K in ultra high vacuum. The character of the orbitals is determined comparing the experimental data with DFT calculations. When the molecular coverage is increased the molecules begin to form chains that finally cover completely the graphene surface. The STS measurements and DFT calculations show that the interaction between the TCNQ molecules is via a saturated C≡N...H-C bonds. STM images show the formation of a spatially extended intermolecular band connecting the TCNQ molecules [5].

[1] B. Borca, S. Barja et al., *New J. Phys.* 12, 093018 (2010).

[2] D. Stradi, S. Barja et al., *Phys. Rev. Lett.* 106, 186102 (2011).

[3] A.L. Vázquez de Parga, F. Calleja et al., *Phys. Rev. Lett.* 100, 106802 (2008).

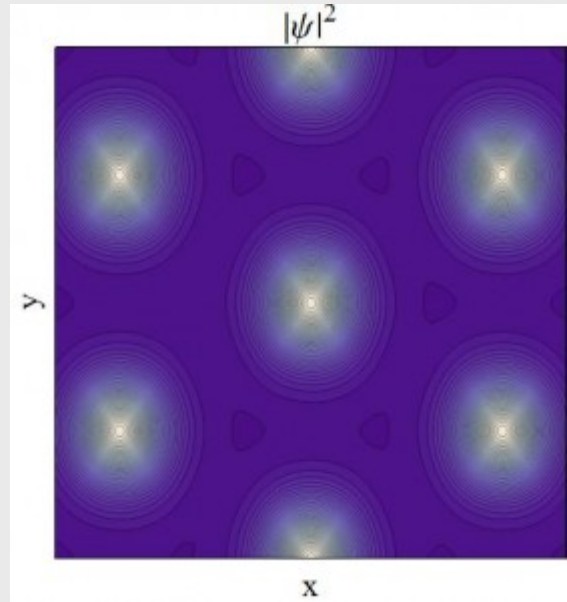
[4] B. Borca, S. Barja et al, *Phys. Rev. Lett.* 105, 036804 (2010).

[5] M. Garnica, D. stradi et al, *submitted* (2012).

---

[Non-Abelian gauge fields in twisted bilayer graphene](#)

Wednesday, 11th April 2012. 12:00-13:00



*Pablo San Jose*

Instituto de Estructura de la Materia, CSIC, Madrid

ABSTRACT:

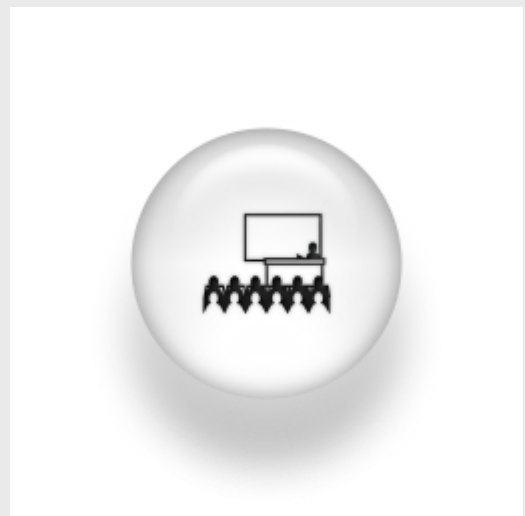
We present an overview of the modeling of low energy twisted graphene bilayers and of its unusual electronic properties. These include charge confinement around zero energy and velocity suppression at recurrent special twist angles. We show that these come as a consequence of non-Abelian gauge fields that arise from the spatial Moiré pattern in interlayer couplings.

---

## Fano interference and infrared phonon activity in bilayer graphene

Thursday, 23th February 2012. 12:00-13:00

*Emmanuele Cappelluti*



CNR, Roma & Instituto de Ciencia de Materiales de Madrid, CSIC

ABSTRACT:

The detection and analysis of the spectral properties of optical phonon in single-layer and multilayer graphene provides a powerful tool not only for a careful characterization of the systems but also for investigating the role of the underlying electron-phonon

interaction.

Recent experiments in gated bilayer graphene revealed a clear phonon resonance at  $1590\text{ cm}^{-1}$  with several interesting features, as for instance a giant enhancement of the phonon intensity as a function of the gate voltage as well as a pronounced Fano lineshape asymmetry.

In this talk I will discuss how these features can be analyzed and predicted on a microscopic quantitative level using a charge-phonon theory applied to the specific case of graphene systems.

We show in particular how the phonon intensity and the Fano asymmetry are strictly related, stemming out from the quantum interference between the electronic and phononic degrees of freedom.

Within this context we are also able to elucidate the relative role of the  $E_u$  and  $E_g$  phonon modes in regards to the infrared activity and the Fano asymmetry of the observed phonon peaks.

We present thus a complete phase diagram for the strength of the phonon modes and their Fano properties as functions of the chemical potential and of the gated-induced electronic gap, showing that a switching mechanism between the dominance of the  $E_u$  or  $E_g$  mode can be controlled by the external gate voltage.

Our work permits thus reconciling within a unique theoretical approach the phonon-peak features observed by different experimental groups, and it provides an analytical tool for predicting and controlling on a quantitative level the spectral properties of the phonon resonances in the infrared spectra of graphenes.

---