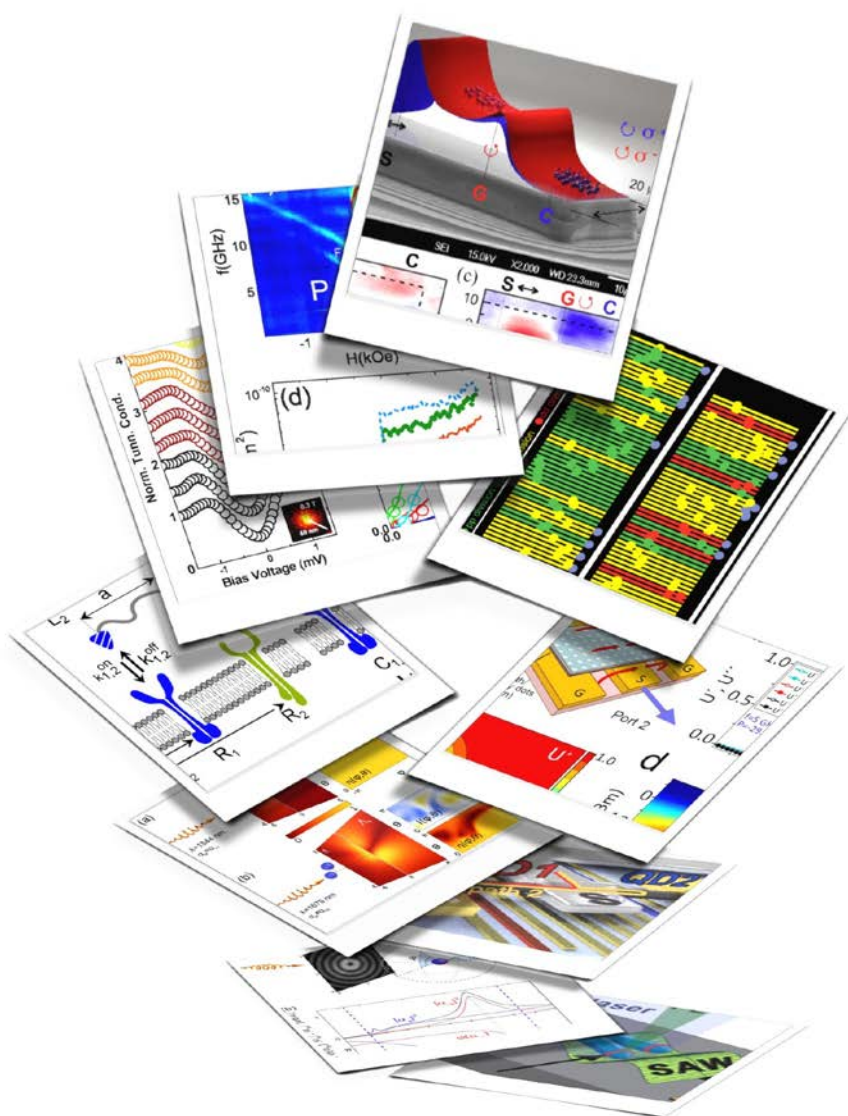


# Instituto Universitario de Ciencia de Materiales Nicolás Cabrera

Activity Report 2015





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# Welcome

A much quoted sentence, attributed by many to Aristotle, reads “We are what we repeatedly do. Excellence, then, is not an act, but a habit”. When we look at the definition of [excellent Science](#) at the EU, it's quite clear that the habits of many institutions at our University are not in line with excellent Science. This contrasts the situation of the daily lives of members of the INC. Many of us participate in [IFIMAC](#) that has been awarded by a grant of the María de Maeztu excellence program. One of our members received the [first full ERC StG](#) at our Institute. And the participation in FET programs, such as the recent [Quantum Technologies](#) initiative, are being discussed by some of us. Excellent science also grows rapidly in our environment—the percentage of ERC grantees funded by our national system is close to 10% in some areas.

The Nicolás Cabrera Institute develops several instruments to support excellent Science. Our Summer School brings outstanding researchers to our Campus. The Institute is thankful to the organizers of this year's School, Profs. Farkhad Aliev, Julio Camarero and Juan José Palacios. The next Summer School is co-organized by Profs Raúl Guantes, David Gómez Miguez and by [Victor Muñoz](#). Muñoz is Professor at the CEI UAM+CSIC, ERC AdG and has been, in addition, highly successful within the US funding system in the past. I would like to particularly thank our Vicerrector for research, Prof Rafael Garesse Alarcón, who invited Victor Muñoz to participate in this Summer school. Having ERC grantees organizing a Summer School is new and we will make all in our hands to make sure that it becomes a habit.

The Colloquia have created an atmosphere that joins highly reputed science and an informal outset, with pictures in the announcements that are being enjoyed both by speakers and students. We have been also able to organize, together with our Departments, well paid grants for our students wanting to make research. Students have presented their jobs at our young researchers meeting. During 2015, two members of the Institute released a [dissemination video](#), supported by the American Physical Society.

I take advantage of this report to acknowledge all members of the INC for re-electing the board for another four years term. Our present challenge is very simple, to develop our habit in excellent Science, with the hope of permeating as many of our close-by institutions as possible. We will continue improving the instruments we have set-up during these four years and add new initiatives. We will make the INC an ERC friendly institution, helping grantees efficiently managing their projects and making sure that they can take full advantage of our services. We will reward excellent Science in all decision making and improve the visibility of our Summer School by actively fostering the participation of internationally highly visible scientists in its organization.

Some of our most successful work is made with our [scanning probe microscopes](#). Images are indeed powerful and convincing, sometimes more than anything else. Recently, I read a [quote](#) referring to a window that frames a landscape in Eagle, Alaska, “*The window is synecdoche, is Eagle itself—a lens, a monocular, framing the wild, holding the vision that draws people up the long trail to the edge of things to have a look and see*”. Maybe images are indeed useful in the course along Vannevar Bush' endless frontier, because they help us framing relevant problems. Successfully using our microscopes, or any one of the other scientific tools we have built or developed, is certainly the best habit to excel in Science.

Hermann Suderow, Director of the INC

# Nicolás Cabrera Summer School

The Nicolás Cabrera Summer School is held since 1994. Since 2002, the Summer School receives support from the Frontiers of Science program of the [Fundación BBVA](#).



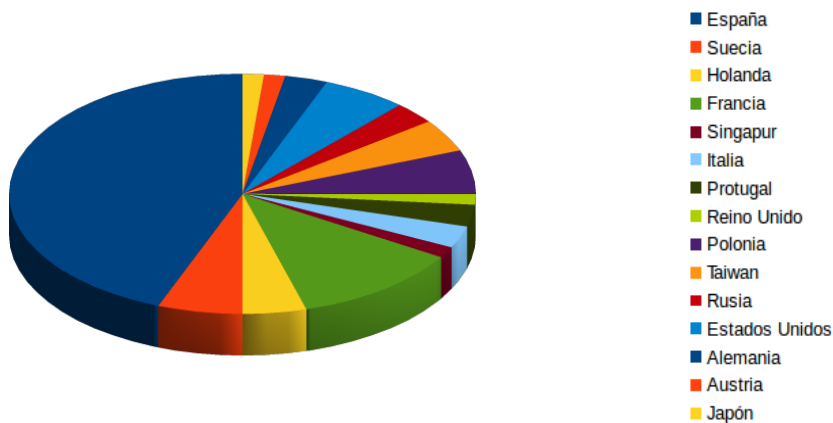
The Fundación BBVA made a press release about this years summer school, see [this link](#).

The 2015 Summer School was organized by Farkhad Aliev, Juan José Palacios y Julio Camarero and entitled "New Directions in Spintronics and nanomagnetism". It was celebrated during 11-16 July 2015 in Miraflores de la Sierra. The main objective has been to provide a complete overview of experimental advances in spintronics and nanomagnetism, and connect these with most exciting theoretical developments. To this end, we invited leads in the field of spin polarized scanning tunneling microscopy, magnetism and nanoescale molecular magnets, among other frontier fields in magnetism.

The following themes were discussed:

- Nanofabrication.
- Molecular magnetism.
- Organic spintronics.
- Magnetization dynamics, spin torque and skyrmions.
- Application of nanomagnetism in medicine.
- Magnetocalorics.
- New forms to control nanomagnetism.
- Atomic scale magnetism.
- Magnetism for energy.

More than 90 people gathered at UAM's residence "La Cristalera". Approximately 60 of them were PhD students coming from many different countries.



Talks covered topical subjects in the field. Speakers were available during the Summer School and the students enjoyed a relaxed atmosphere, where they could encounter and discuss with the leaders in the field. Numerous informal discussions established new scientific relationships.

The students were quite active during the talks and asked speakers after the sessions frequently. There were three poster sessions, where the students had additional opportunities to discuss with the speakers. 32 posters were presented, and the organizers gave three prizes to the best poster presentations. The school was positively evaluated by participants, through personal interviews. The format chosen, consisting of two talks by the invited speakers, was very successful. In the first talk (50 minutes) they made an introduction to their techniques and in the second talk (30 minutes), they gave concrete and recent examples.

The senior invited speakers were:

Jagadeesch Moodera (MIT, Boston, USA)

Shinji Yuasa (AIST, Tsukuba, Japan)

Berend Jonker (NRL, Washington DC, USA)

Javier Tejada (Universidad de Barcelona, Spain)

Minn-Tsong Lin (National Taiwan University, Taiwan)

Julie Grollier (UMP/CNRS/Thales, Paris, France)

Roland Wiesendanger (Univ .Hamburg, Germany )

Stephen Russek (NIST, Boulder, USA)

Yaroslav Tserkovnyak (UV Los Angeles, USA)

Sergio Valenzuela (ICN2, Barcelona, Spain)

Johan Akerman (University of Gothenburg, Sweden)

José María de Teresa (INA, Zaragoza, Spain)

Eugenio Coronado (Universidad de Valencia, Spain)

Joaquin Fernandez Rossier (INL, Braga, Portugal)

Wolfgang Kuch (Freie Universität Berlin, Germany)

Jan Vogel (Louis Néel Laboratory, Grenoble, France)

Viente Cros (UMP/CNRS/Thales, Paris, France)

Ursula Ebels (SPINTEC, Grenoble, France)

Rodolfo Miranda (IMDEA Nanoscience, Spain)



And we further had the following speakers:

Marius Costache (ICN2, Barcelona, Spain)

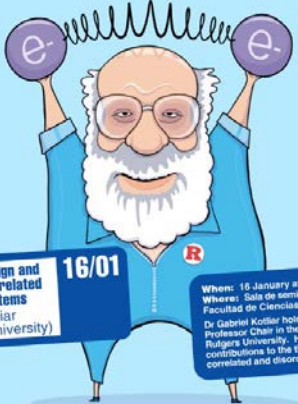
Ruben Guerrero (IMDEA Nanoscience, Spain)

Juan Pedro Cascales (UAM, Madrid, Spain)

# Colloquia

With the collaboration of the Fundación BBVA, we organize the colloquia "Frontiers in Condensed Matter Physics". They are dedicated to Prof. Nicolás Cabrera. This year, **Gabriel Kotliar (Rutgers University)**, spoke about "*Material Design and Strongly Correlated Electron Systems*", **Louis Taillefer** gave a talk on "*Superconductors: the Magic and the Mystery*," **Jean Dalibard** presented "*Exploring Flatland with cold atomic gases*" and **Carlo Beenakker** introduced "*Majorana braiding in superconductors: How to operate on a Zen particle*". The students of UAM and the younges reseachers positively value this initiative. Some of the talks are available in [Youtube](#).


**Colloquium Frontiers of Condensed Matter Physics 2015**  
Dedicated to Prof. Nicolás Cabrera (1913-1989)



**Material Design and Strongly Correlated Electron Systems**  
16/01  
Gabriel Kotliar (Rutgers University)

When: 16 January at 12h30  
Where: Sala de seminarios, módulo 00, Facultad de Ciencias, UAM  
Dr. Gabriel Kotliar holds a Board of Governors Professor Chair in the Physics Department at Rutgers University. He is well known for his contributions to the theory of strongly correlated and disordered electron systems.

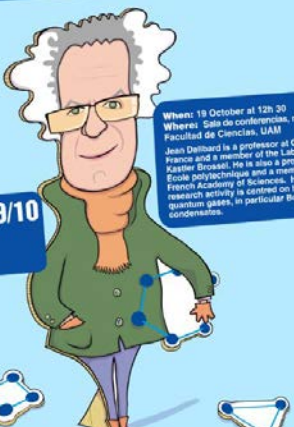
**Colloquium Frontiers of Condensed Matter Physics 2015**  
Dedicated to Prof. Nicolás Cabrera (1913-1989)



**"Electrons in copper oxides: Charge density waves and high-temperature superconductivity"**  
16/04  
Louis Taillefer

When: 16 April at 12h30  
Where: Sala de conferencias, módulo 0, Facultad de Ciencias, UAM  
Dr. Louis Taillefer is Professor at SherBrooke University and Director of CPAR's Quantum Materials program. He investigates why some materials exhibit remarkable electronic properties, such as magnetism and superconductivity.


**Colloquium Frontiers of Condensed Matter Physics 2015**  
Dedicated to Prof. Nicolás Cabrera (1913-1989)



**"Exploring Flatland with cold atomic gases"**  
19/10  
Jean Dalibard

When: 19 October at 12h 30  
Where: Sala de conferencias, módulo 0, Facultad de Ciencias, UAM  
Jean Dalibard is a professor at Collège de France and a member of the Laboratoire Kastler Brossel. He is also a professor at Ecole polytechnique and a member of the French Academy of Sciences. His current research activity is centered on the study of quantum gases, in particular Bose-Einstein condensates.

**Colloquium Frontiers of Condensed Matter Physics 2015**  
Dedicated to Prof. Nicolás Cabrera (1913-1989)



**"Majorana braiding in superconductors: How to operate on a Zen particle"**  
05/11  
Carlo Beenakker

When: 5 November at 12h 30  
Where: Sala de conferencias, módulo 0, Facultad de Ciencias, UAM  
Carlo Beenakker is a professor at Leiden University, working in the Lorentz Institute for theoretical physics. His current research aims at the design of the building blocks for a quantum computer based on superconducting nanostructures.

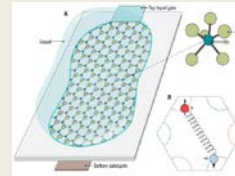


# Science at INC

All papers of the INC members can be found in our webpage. Here we highlight a few of them.

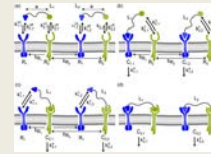
## Opening the gate on superconductivity, H. Suderow, *Science* **11**, 1316 (2015).

The deleterious effect of the magnetic field on superconductivity has plagued researchers and engineers alike for more than a century. Quantized vortices appear in most superconductors when applying a magnetic field and move under a current, creating dissipation that destroys the superconducting state. By pinning their motion through complex materials engineering, powerful magnets can be built for use in resonance imaging for medicine or to levitate trains.



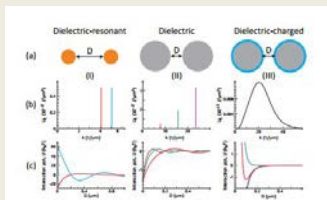
## Synergistic interaction between Selective Drugs in Cell Populations Models, V. Doldan, D. G. Miguez, *Plos one* **10**, e0117558 (2015).

The design of selective drugs and combinatorial drug treatments are two of the main focuses in modern pharmacology. In this study we use a mathematical model of chimeric ligand-receptor interaction to show that the combination of selective drugs is synergistic in nature, providing a way to gain optimal selective potential at reduced doses compared to the same drugs when applied individually.



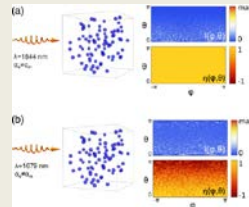
## Controlling dispersion forces between small particles with artificially created random light fields G. Brügger, L. S. Froufe-Pérez, F. Scheffold; et al., *Nature Communications* **6**, 7460, (2015).

Appropriate combinations of laser beams can be used to trap and manipulate small particles with optical tweezers as well as to induce significant optical binding forces between particles. These interaction forces are usually strongly anisotropic depending on the interference landscape of the external fields.



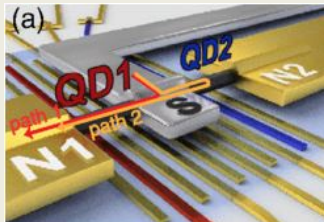
**Isotropically Polarized Speckle Patterns, M.K.Schmidt, J. Aizpurua, X. Zambrana-Puyalto, et al, Physical Review Letters **114** 113902, (2015).**

The polarization of the light scattered by an optically dense, random solution of dielectric nanoparticles shows peculiar properties when the scatterers exhibit strong electric and magnetic polarizabilities. While the distribution of the scattering intensity in these systems shows the typical irregular speckle patterns, the helicity of the incident light can be fully conserved when the electric and magnetic polarizabilities of the scatterers are equal



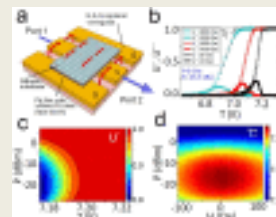
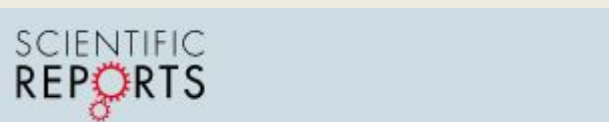
**Magnetic Field Tuning and Quantum Interference in a Cooper Pair Splitter, G. Fülöp, F. Dominguez, D. d'Hollosy, et al, Physical Review Letters **115**, 227003, (2015).**

Cooper pair splitting (CPS) is a process in which the electrons of the naturally occurring spin-singlet pairs in a superconductor are spatially separated using two quantum dots. Here, we investigate the evolution of the conductance correlations in an InAs CPS device in the presence of an external magnetic field.



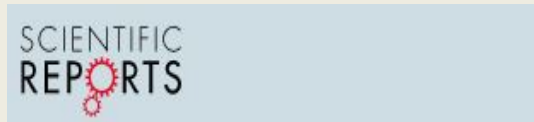
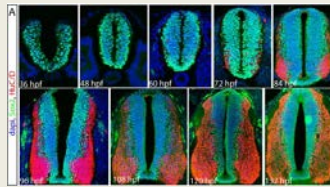
**Microwave-stimulated superconductivity due to presence of vortices, A. Lara. F.G. Aliev, A.V. Silhanek, et al, Scientific Reports **5**, 9187, (2015).**

The response of superconducting devices to electromagnetic radiation is a core concept implemented in diverse applications, ranging from the currently used voltage standard to single photon detectors in astronomy. Surprisingly, a sufficiently high power subgap radiation may stimulate superconductivity itself.



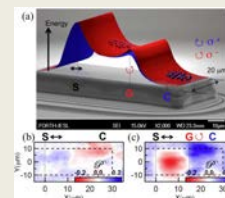
**A Branching Process to Characterize the Dynamics of Stem Cell Differentiation, D. G. Miguel., Scientific Reports 5 13265, (2015).**

The understanding of the regulatory processes that orchestrate stem cell maintenance is a cornerstone in developmental biology. Here, we present a mathematical model based on a branching process formalism that predicts average rates of proliferative and differentiative divisions in a given stem cell population. In the context of vertebrate neurogenesis, the model predicts complex non-monotonic variations in the rates of pp, pd and dd modes of division as well as in cell cycle length, in agreement with experimental results.



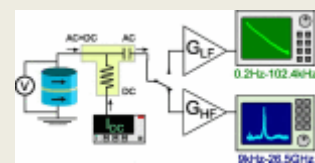
**Spin Selective Filtering of Polariton Condensate Flow, T. Gao, C. Antón, T.C.H. Liew, et al., Applied Physics Letters 107 011106, (2015).**

Spin-selective spatial filtering of propagating polariton condensates, using a controllable spin-dependent gating barrier, in a one-dimensional semiconductor microcavity ridge waveguide is reported. A nonresonant laser beam provides the source of propagating polaritons, while a second circularly polarized weak beam imprints a spin dependent potential barrier, which gates the polariton flow and generates polariton spin currents. A complete spin-based control over the blocked and transmitted polaritons is obtained by varying the gate polarization



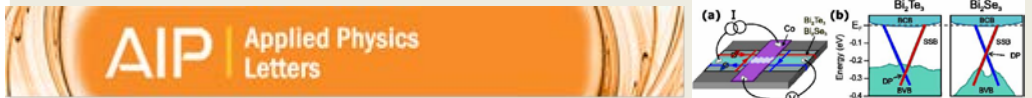
**Detection of spin torque magnetization dynamicsthrough low frequency noise, J.P.Cascales, D. Herranz, U. Ebels, et al, Applied Physics Letters 107,052401, (2015).**

We present a comparative study of high frequency dynamics and low frequency noise in elliptical magnetic tunnel junctions with lateral dimensions under 100 nm presenting current-switching phenomena. The analysis of the high frequency oscillation modes with respect to the current reveals the onset of a steady-state precession regime for negative bias currents above  $J=107A/cm^2$ , when the magnetic field is applied along the easy axis of magnetization



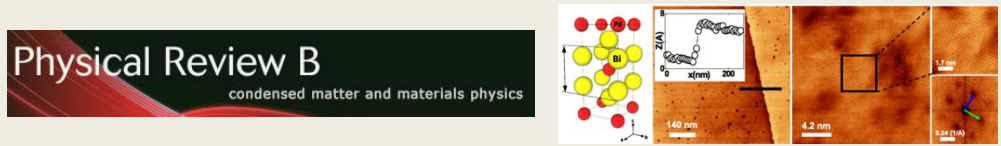
**Band structure of topological insulators from noise measurements in tunnel junctions, J.P. Cascales, I. Martinez, F. Katmis, et al, Applied Physics Letters **107**, 252402, (2015).**

The unique properties of spin-polarized surface or edge states in topological insulators (TIs) make these quantum coherent systems interesting from the point of view of both fundamental physics and their implementation in low power spintronic devices. Here we present such a study in TIs, through tunneling and noise spectroscopy utilizing TI/Al<sub>2</sub>O<sub>3</sub>/Co tunnel junctions with bottom TI electrodes of either Bi<sub>2</sub>Te<sub>3</sub> or Bi<sub>2</sub>Se<sub>3</sub>.



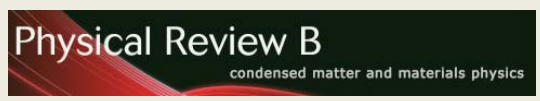
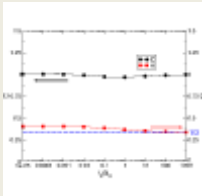
**Magnetic field dependence of the density of states in the multiband superconductor  $\beta$ -Bi<sub>2</sub>Pd, E. Herrera, I. Guillamón, J.A. Galvis, et al., Physical Review B, **92**, 054508. (2015).**

We present very low-temperature scanning tunneling microscopy (STM) experiments on single-crystalline samples of the superconductor  $\beta$ -Bi<sub>2</sub>Pd. We find a single superconducting gap from the zero-field tunneling conductance. However, the magnetic field dependence of the intervortex tunneling conductance is higher than the one expected in a single-gap superconductor.



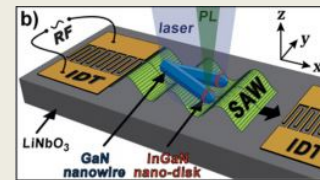
**Effective-mass theory for the anisotropic exciton in two –dimensional crystals: Application to phosphorene, E. Prada, J.V. Alvarez, K.L. Narasimha-Acharya et al, Physical Review B N **91**,245451, (2015).**

We present a theoretical study of the exciton binding energy for anisotropic two-dimensional crystals. We obtain analytical expressions from variational wave functions in different limits of the screening length to exciton size ratio and compare them with numerical solutions, both variational and exact. As an example, we apply these results to phosphorene, a monolayer of black phosphorous



**Dynamic control of the optical emission from GaN/InGaN nanowire quantum dots by Surface acoustic waves, S. Lazic, E. Chernysheva, Z. Gacevic, et al, AIP Advances 5, 097217, (2015).**

The current status of the use of nanoparticles for photothermal treatments is reviewed in detail. The different families of heating nanoparticles are described paying special attention to the physical mechanisms at the root of the light-to-heat conversion processes. The heating efficiencies and spectral working ranges are listed and compared. The most important results obtained in both in vivo and in vitro nanoparticle assisted photothermal treatments are summarized.



**Note: Vectorial-magneto optical Kerr effect technique combined with variable temperature and full angular range all in a single setup, J.L. Cuñado, J. Pedrosa, F. Ajejas; et al, Review of Scientific Instruments 86, 046109, (2015).**

Here, we report on a versatile full angular resolved/broad temperature range/vectorial magneto optical Kerr effect (MOKE) magnetometer, named TRISTAN. Its versatility relies on its capacity to probe temperature and angular dependencies of magnetization reversal processes without the need to do any intervention on the apparatus during measurements. The setup is a combination of a vectorial MOKE bench and a cryostat with optical access.



# Young Researchers Meeting



Snezana Lazic and Elena del Valle organized the Young researchers meeting 2015 in Miraflores de la Sierra. During the meeting, we awarded the “Young researchers prize in materials science” to Antonio Lara Cala for his work “Microwave-stimulated superconductivity due to presence of vortices” made in collaboration with INC member Farkhad Aliev, and published in *Scientific Reports* 5, 9187 (2015). We gave the second prize to Rubén Seoane Souto, for his work “Transient dynamics and waiting time distribution of molecular junctions in the polaronic regime” in collaboration with Alfredo Levy Yeyati and published in *Physical Review B* 92, 125435 (2015). The jury was headed by Prof. José María Calleja Pardo, and Profs José Ortega and D. Miguel Manso took also part in it. They were all impressed by the excellent quality of the work presented by the candidates. José Benito Llorens and other colleagues made a nice [video](#) of the meeting. During the meeting, we organized a poster session and the following talks were given:

- *“Graphene on Rhodium: Growth and Uncoupling Unveiled Through its Corrugation Behaviour”* Ana Martín Recio, (Departamento de Física de la Materia Condensada).
- *“Spatial variation of a giant spin-orbit coupling effect induces electron confinement in graphene on Pb islands”*. Juan Jesús Navarro (Departamento de Física de la Materia Condensada, IMDEA).
- *“Acoustically induced dynamic tuning of the optical emission from GaN/InGaN nanowire quantum dots”*, Ekaterina Chernysheva (Departamento de Física de Materiales).
- *“In vivo controlled phototherapy based on multifunctional luminescent nanoparticles”*, Blanca del Rosal, (Departamento de Física de Materiales).
- *“Ultrafast photochemical reactions in DNA: a QMMM study”*, José I. Mendieta Moreno (Departamento de Física Teórica de la Materia Condensada).
- *“Graphene monovacancies: electronic and mechanical properties from large scale ab initio simulations”*, Lucía Rodrigo, (Departamento de Física Teórica de la Materia Condensada).
- *“Extreme near-field radiative heat transfer”*, Víctor Fernández Hurtado, (Departamento de Física Teórica de la Materia Condensada).
- *“Cu<sub>2</sub>ZnSn(S,Se)<sub>4</sub> Kesterite material for solar cells devices”* Eduardo García Llamas, (Departamento de Física Aplicada).

## Prizes for Physics students

We organized, with the support of the Departments Física de la Materia Condensada, Física teórica de la Materia Condensada, Física de Materiales and Física aplicada, five grants to support excellent students who want to start doing research in our laboratorios. Students presented their work in the Young Researchers meeting of the Institute. The awarded students have been:

- López Piqueras, Javier, tutor Carlos Cuevas Rodríguez, "so-called near-field radiative energy transfer"
- Rodríguez Muñoz, Marcos, tutor Lola Martín, "Dinámica de Condensados de polaritones en estructuras uno dimensionales".
- Gonzalez Badia, Eduardo, tutor, Francisco José García Vidal and Esteban Moreno, "Exciton transport assisted by electromagnetic strong coupling".
- Llorente Fernandez, Fernando José, tutor Juan José Palacios, trabajo "Teoría y simulación de cristales bidimensionales".
- Alvarado Herrero, Miguel, tutora Miguel Manso Silvan, "Crecimiento por métodos híbridos de reflectores de Bragg

We also supported one student, Reino Mateo, Juan, who made a video "[Dinámica Molecular de los Sistemas Biológicos](#)" together with José Ortega Mateo.

# Publications

**H. Suderow:**

*Opening the gate on superconductivity.*  
Science **350**, 1316, (2015).

**A. Martín Recio, A.J. Martínez-Galera, J.M. Gómez-Rodríguez.**

*Surface Diffusion of Azabenzene s-Triazine Molecules on a Strong Interacting Graphene-Metal System.*  
Journal of Physical Chemistry C, **119**, 1, 401, (2015).

**H. Alarcon, M.D. Ynsa, Z.Y. Dang, et al.**

*Conditioned bio-interfaces of silicon/porous silicon micro-patterns lead to the chondrogenesis of hMSCs.*  
RSC Advances **5**, 112, 92263, (2015).

**D. de las Heras, E. Velasco, Y. Martínez-Ratón.**

*Capillary and winding transitions in a confined cholesteric liquid crystal.*  
Soft Matter **11**, 35, 7038, (2015).

**M. Gonzalez-Pinto, Y. Martínez Ratón, E. Velasco, et al.**

*Effect of shape biaxiality on the phase behavior of colloidal liquid-crystal monolayers.*  
Physical Chemistry Chemical Physics **17**, 9, 6389, (2015).

**A. Lara, F.G. Aliev, A.V. Silhanek, et al.**

*Microwave-stimulated superconductivity due to presence of vortices.*  
Scientific Reports **5**, 9187, (2015).

**P. Gonzalez de Prado Salas, M. Encinar, A. Alvaro, et al.**

*Modeling the interplay between protein and lipid aggregation in supported membranes.*  
Chemistry and Physics of Lipids **185**, 141, (2015).

**J.A. Galvis, E. Herrera, I. Guillamón, et al.**

*Three axis vector magnet set-up for cryogenic scanning probe microscopy.*  
Review of Scientific Instruments **86**, 013706, (2015).

**M.K. Schmidt, J. Aizpurua, X. Zambrana-Puyalto, et al.**

*Isotropically Polarized Speckle Patterns.*  
Physical Review Letters **114**, 113902, (2015).

**D. Cabrera, J. Camarero, D. Ortega, et al.**

*Influence of the aggregation, concentration, and viscosity on the nanomagnetism of iron oxide nanoparticle colloids for magnetic hyperthermia.*  
Journal of Nanoparticle Research **17**, 121, (2015).

**J.C. del Valle, E. Camarillo, L. Martínez Maestro, et al.**

*Dielectric anomalous response of water at 60*

*degrees C.*  
Philosophical Magazine **95**, 683, (2015).

**V. Doldan Martelli, D. G. Miguez.**

*Synergistic Interaction between Selective Drugs in Cell Populations Models.*  
Plos one **10**, e0117558, (2015).

**C. Anton, S. Morina, T. Gao, et al.**

*Optical control of spin textures in quasi-one-dimensional polariton condensates.*  
Physical Review B **91**, 075305, (2015).

**R. Caminati, G. Cwilich, L.S. Froufe-Pérez, et al.**

*Speckle fluctuations resolve the interdistance between incoherent point sources in complex media.*  
Physical Review A **91**, 023807, (2015).

**D. Gallach Pérez, E. Quijoma, R. Sanz, et al.**

*Nanotopography enhanced mobility determines mesenchymal stem cell distribution on micropatterned semiconductors bearing nanorough areas.*  
Colloids and Surfaces B-Biointerfaces **126**, 146, (2015).

**J. Merino, J.V. Álvarez.**

*Charge fluctuations in the unconventional metallic state of Li<sub>0.9</sub>Mo<sub>6</sub>O<sub>17</sub>.*  
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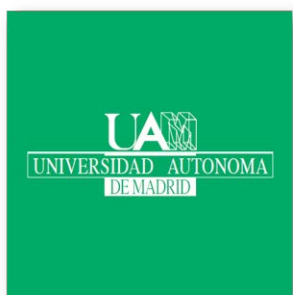
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