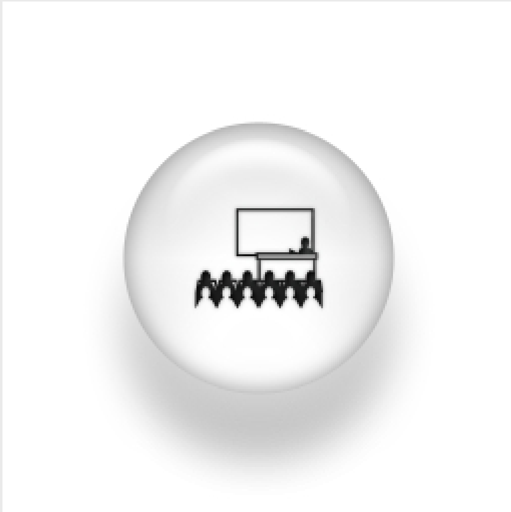
Qantum Effects in Plasmonic Nanostructures

Thursday, 16th February 2012. 12:00-13:00



Pablo García González

Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid

ABSTRACT:

One of the most attractive aspects of surface plasmon polaritons is their ability to collect and concentrate light into sub-wavelength volumes. The theoretical description of the relevant processes is often done by using classical local optics. However, the miniaturization in the fabrication of plasmonic devices is approaching the limit where non-local effects in the optical response of a metal cannot be neglected.

A possible way to take into account these effects is the modelling of the metal permittivity through hydrodynamical approximations [1]. Nevertheless, the predictive accuracy of such methods depends very sensitively on the details of the model permittivity. At a more fundamental level, the electron response of a system can be evaluated by using time-dependent density functional theory (TDDFT) [2]. Under this prescription, non-local and quantum-mechanical effects in the optical response are treated on the same footing.

In this informal seminar, I shall present some preliminary results of the TDDFT optical response of two metal nanowires in close proximity (sub-nanometric) to each other. A comparison with the corresponding hydrodynamic and local responses in the limit of zero separation will be presented as well.

Work done in collaboration with Lorenzo Stella and Angel Rubio (UPV/EHU), and F.J. García Vidal (UAM).

[1] A.I. Fernandez-Dommnguez, A. Wiener, F.J. Garcma-Vidal, S.A. Maier and J.B. Pendry (in press).

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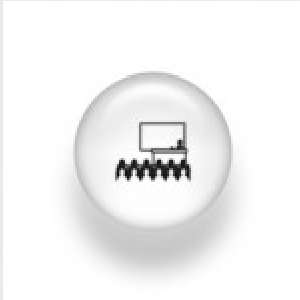
Electronic transport in defective low dimensional carbon materials: nanotubes and graphene

Wednesday, 8th February 2012. 12:00-13:00



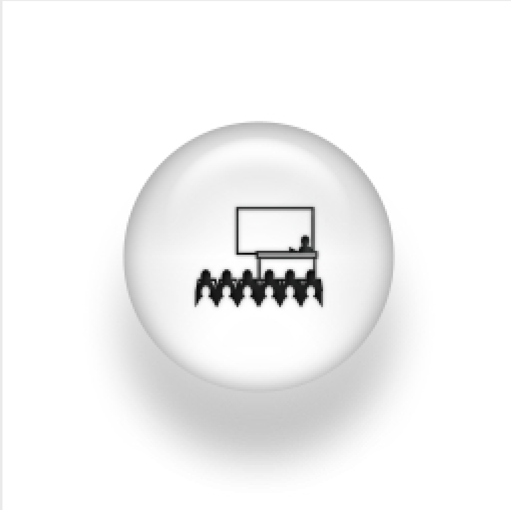
Cristina Gomez-Navarro

Departamento de Física de la Materia Condensada, Universidad Autónoma de Madrid

ABSTRACT:
Electronic transport properties of carbon nanotubes and graphene are of interest due to their potential use in future electronic devices but also from a fundamental point of view. These materials, due to their low dimensionality and peculiar band structure, present a broad spectrum of electronic transport regimes.
In this talk I will first talk about our experimental work on carbon nanotubes focusing on the effect of different scattering mechanism: atomic scale defects [1] and high energy phonons [2], I will finish trying to give an overview of the phase diagram of electronic transport in carbon nanotubes.
Then I will focus on our work on chemically derived graphene. These graphene layers are obtained by a mass production technique based in the oxidation and subsequent reduction of graphite [3]. I will describe our experiments with the aim of characterizing this material from a structural [4], electronic [3,5] and mechanical [6] point of view. I will also discuss a route for enhancement of its conductivity [7].
[1] Gomez-Navarro, C. et al., Tuning the conductance of single-walled carbon nanotubes by ion irradiation in the Anderson localization regime. Nat Mater
4 (7), 534 (2005).
[2] Sundqvist, P. et al., Voltage and length-dependent phase diagram of the electronic transport in carbon nanotubes. Nano Letters 7 (9), 2568 (2007).
[3] Gomez-Navarro, C. et al., Electronic Transport Properties of Individual Chemically Reduced Graphene Oxide Sheets. Nano Letters 7 (11), 3499 (2007).
[4] Gomez-Navarro, C. et al., Atomic Structure of Reduced Graphene Oxide.
Nano Letters 10 (4), 1144 (2010).
[5] Kaiser, A. et al., Electrical Conduction Mechanism in Chemically Derived Graphene Monolayers. Nano Letters 9 (5), 1787 (2009).
[6] Gomez-Navarro, C., Burghard, M., and Kern, K., Elastic properties of chemically derived single graphene sheets. Nano Letters 8 (7), 2045 (2008).
[7] Lopez, V. et al., Chemical Vapor Deposition Repair of Graphene Oxide: A Route to Highly Conductive Graphene Monolayers. Advanced Materials 21 (46),
4683 (2009).

On the optical properties of graphenes

Wednesday, 1st February 2012. 12:00-13:00



Tobias Stauber

Departamento de Física de la Materia Condensada, Universidad Autónoma de Madrid

ABSTRACT:
One of the hallmarks of the optical properties of (suspended) graphene is that a simply-observable quantity as the optical transparency is defined solely by the fine structure constant [1]. In the first part of this talk, I will give the theoretical explanation to this experiment, i.e., show that even in the visible-optics regime the corrections to the Dirac cone approximation are small (a few percent) and the effect of next-nearest neighbor hopping is negligible [2]. I will also discuss the infrared conductivity of graphene on a substrate where electron-phonon and impurity scattering become important [3].
In the second part, I will look at the optical properties of double layer graphene with respect to their plasmonic excitations, near-field amplification and extraordinary (perfect) transmission [4]. Also graphene’s fluorescence quenching including transverse decay channels and full retardation will be discussed [5]. Finally, the current-current correlation function of the full hexagonal tight-binding model will be derived [6] and I will show that lattice effects lead to a paramagnetic response for graphene with intrinsic doping at low temperatures [7].

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[3] T. Stauber, N. M. R. Peres, and A. H. Castro Neto, Phys. Rev. B 78, 085418 (2008).
[4] T. Stauber and G. Gómez-Santos, Phys. Rev. B 85, (2012).
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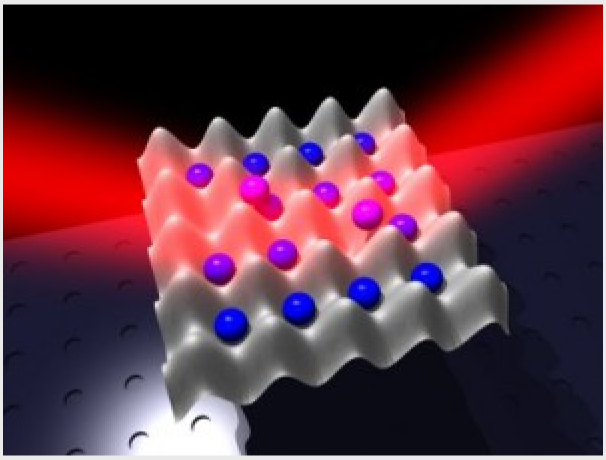
Quantum Information for Molecular Physics



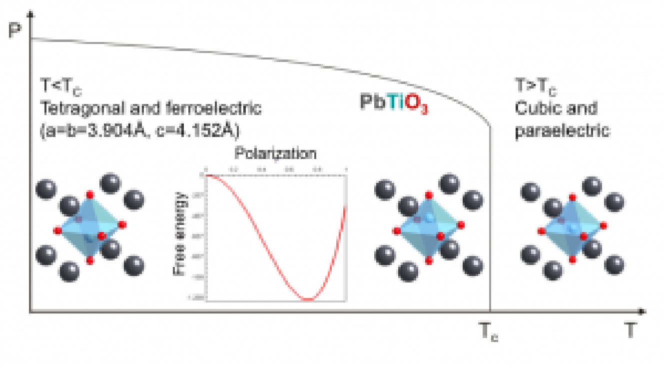
Thursday, 26th January 2012. 12:00-13:00

Jordi Mur-Petit

Instituto de Fisica Fundamental, CSIC

ABSTRACT:
I will make a presentation of the field of quantum information processing (QIP) from a general perspective, focusing then on our research on both the use of cold molecules for QIP tasks, and the use of QIP methods to address molecular physics problems, such as spectroscopy of molecular ions. I will finally discuss our ongoing research on controlled collisions with finite-range potentials.

First-Principles Simulations on PbTiO3/SrTiO3 Superlattices



Thursday, 19th January 2012. 12:00-13:00

Javier Junquera

Departamento de Ciencias de la Tierra y Física de la Materia Condensada, Universidad de Cantabria

ABSTRACT:
Ferroelectric perovskites are materials of great fundamental and applied interest. This family of materials displays a great range of functionalities, from ferroelectricity to superconductivity. More interestingly, perovskites show a very rich phase diagram allowing for a great tunability playing with doping, epitaxial strain, and the combination

of different materials in heterostructures. This has led to the discovery of completely new interface-based phenomena in the last years, for instance a fundamentally new type of ferroelectricity has been discovered in PbTiO3/SrTiO3 superlattices, due to the unexpected coupling of ferroelectric and antiferrodistortive structural distortions in these heterostructures [1].

First in this talk, we will present first-principles calculations, within the density functional theory, on the coupling between epitaxial strain, polarization, P, and oxygen octahedra rotations in monodomain (PbTiO3)n/(SrTiO3)n superlattices [2]. We have studied different periodicities, n ranged from 1 to 3, with an improper ferroelectric behaviour. P is found to be extremely sensitive to strain, and rotates continuosly from a c-phase (P oriented along the [001] direction) for compressive strains, to an aa-phase (P along [110]) under tensile strain. The out-of-plane component of P, Pz, is always preserved at the interface to minimize the electrostatic energy, and decreases in the PbTiO3 layer with respect the bulk value, reflecting the energy cost of polarizing SrTiO3. At the origin of these new phases with an in-plane component of P, we have found the preference of the polarization in PbTiO3 to rotate, over an homogeneous decrease of Pz. Around the lattice constant imposed by a SrTiO3 substrate, the system displays a large piezoelectric reponse. Changes in polarization are strongly coupled with the response of the oxygen octahedra, whose rotations and tiltings cannot be explained by the usual steric arguments alone. Instead a covalent model on the polarization-tilting coupling is developed.

Second, following the suggestion of a recent experimental work [3], who suggested that the ground state of this system might be actually polydomain for most periodicities, we will also report on simulations on PbTiO3/SrTiO3 superlattices including the presence of domains to complement the last experimental results and to better understand the properties of domain structures in these superlattices.

This work was supported by the Spanish Ministery of Science and Innovation through the MICINN Grant FIS2009-12721-C04-02; by the Spanish Ministry of Education through the FPU fellowship AP2006-02958; and by the European Union through the project EC-FP7, Grant No. NMP3-SL-2009-228989 “OxIDes”. The authors thankfully acknowledge the computer resources, technical expertise and assistance provided by the Red Española de Supercomputación.

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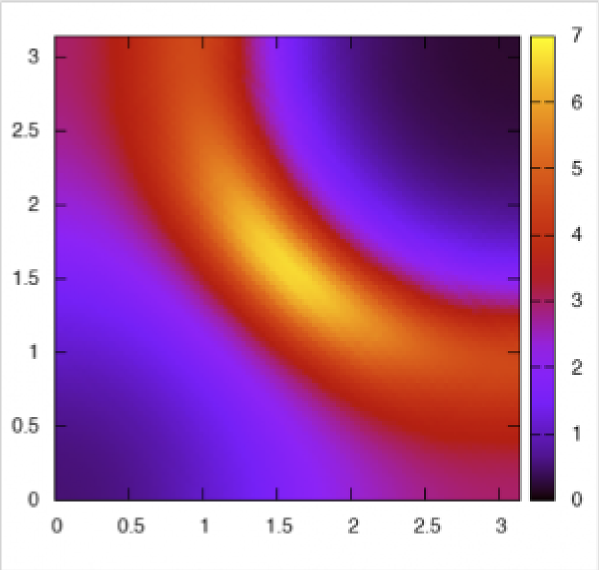
[2] P. Aguado-Puente, P. García-Fernández, and Javier Junquera, Phys. Rev. Lett. 107, 217601 (2011).

[3] P. Zubko et al. Phys. Rev. Lett. 104, 187601 (2010).

Towards a microscopic description of the pseudogap phase in cuprate and organic

superconductors

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



Jaime Merino

Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid

ABSTRACT:

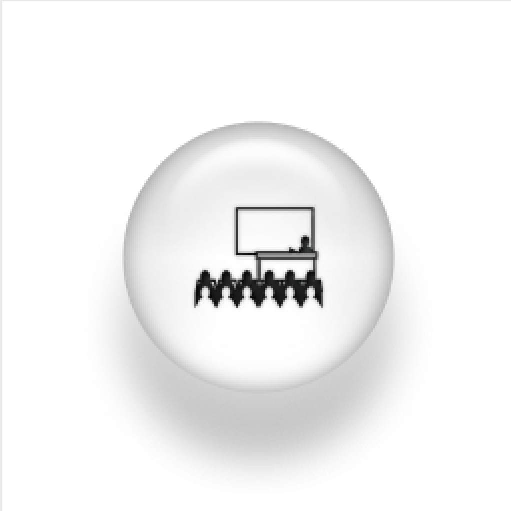
Understanding the mechanism of high-Tc superconductivity in cuprate materials is a fundamental challenge in condensed matter theory. The ‘normal’ metallic phase of these systems is highly unconventional displaying strong deviations from Landau-Fermi liquid behavior particularly in the underdoped regime in which a pseudogap phase with no apparent broken symmetry occurs. The most ‘anomalous’ observation in this phase is that the Fermi surface consists of disconnected arcs along the Brillouin zone diagonals violating the Luttinger sum rule condition. A pseudogap phase has also been observed in the metallic phase of layered organic materials which are in close proximity to a Mott insulating phase. The common existence of a pseudogap state in the doping driven Mott insulators (cuprates) and in the bandwidth Mott transition (organics) suggests that the pseudogap is inherent to properties of the Mott insulator in two-dimensional systems.

In order to understand the microscopic origin of the pseudogap phase we have explored the evolution of the one-electron properties across the Mott metal-insulator transition based on a single-band half-filled Hubbard model on a two-dimensional square lattice. As the Coulomb repulsion is increased electrons along the antinodal direction of the Brillouin zone open a gap (pseudogap) in the spectral density whereas electrons along the nodal direction display a quasiparticle-like peak. Since the pseudogap phase is found in the paramagnetic solution of the Hubbard model no broken symmetry occurs suggesting that is associated with short range electronic correlations. The nature of the excitations in the pseudogap phase is unveiled by analyzing pairing and antiferromagnetic correlations. We find that dx2-y2-wave pairing correlations are enhanced whereas antiferromagnetism is suppressed within the pseudogap phase. This behavior is consistent with the resonant valence bond (RVB) wavefunction for the

ground state proposed by Anderson and coworkers for the cuprate superconductors.

Pi-phases and triplet pair correlations in s-wave superfluids as signatures of the FFLO-type states

Wednesday, 21th december 2011. 12:00-13:00

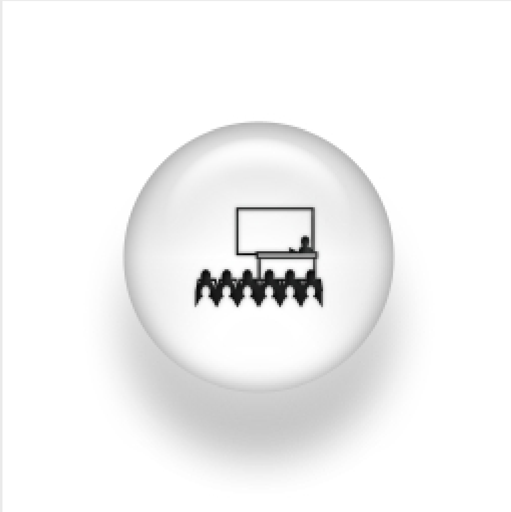


Ivar Zapata
Departamento de Física de Materiales, Universidad Complutense de Madrid
ABSTRACT:
I will introduce FFLO (Fulde-Ferrell-Larkin-Ovchinikov) physics and review the present status of its experimental evidence. Cold atomic physics provides an analog to Superconducting-Ferromagnetic (SF) hetero-structures. As in SF, the order parameter oscillates from positive to negative values (pi-phases). I will show the connection of these states to FFLO-physics. All FFLO-type states show a substantial triplet-mixing in the Cooper pair wave-function. This mixing can be used as an independent test of their existence.

Magnetoplasmonics: The interplay between magneto-optics and plasmonics

Wednesday, 14th december 2011. 12:00-13:00

Antonio García-Martín



Instituto de Microelectrónica de Madrid, CSIC

ABSTRACT:

Subwavelength composite materials constitute an interesting path towards the development of materials with “on demand” optical properties. We will present our latest results on systems composed of both noble and ferromagnetic metals, which we denote as magnetoplasmonic. While noble metals have intense and narrow plasmon resonances they lack magneto-optical (MO) activity at reasonable magnetic field intensities. On the other hand, ferromagnetic metals are MO active but their plasmon resonances are weak and broad. By combining both kinds of materials we intend to obtain systems which simultaneously exhibit plasmon resonances and MO activity. We will show that thus it is possible to both (1) enhance the magneto-optical activity of the system via surface plasmon excitation, and (2) modulate the plasmon properties via application of a magnetic field [1]. Localized surface plasmon resonances (LSPRs) greatly influence the optical [2,3] and magneto-optical (MO) [4,5,6,7,8] properties of fully metallic and metal-dielectric nanostructures. We will analyze the MO response of isolated nanodisks, where we will show how the excitation of the LSPR produces an enhancement of the MO activity [4]. The observed enhancement in the MO is attributed to the high intensity of the electromagnetic (EM) field inside the nanostructure when the LSPR occurs. Here we show how the EM profile related to the LSPR can be probed locally inside the nanostructure by measuring the MO activity of the system as a function of the position a MO active probe (a Co nanolayer) [9]. This EM field profile is the key element in the analysis of the MO activity and thus a clever engineering would make it possible to get large MO effect and low losses [10]. The same kind of structures allows the analysis of the effect of the MO activity on the plasmon properties. We will show that the wavevector of the plasmon is modified upon application of a magnetic field in the transverse configuration [11]. That modification can be used in a wide variety of scenarios: e.g. in active microinterferometry [12,13].

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[6] G.X.Du, et al., Appl. Phys. Lett. 96, 081915 (2010).
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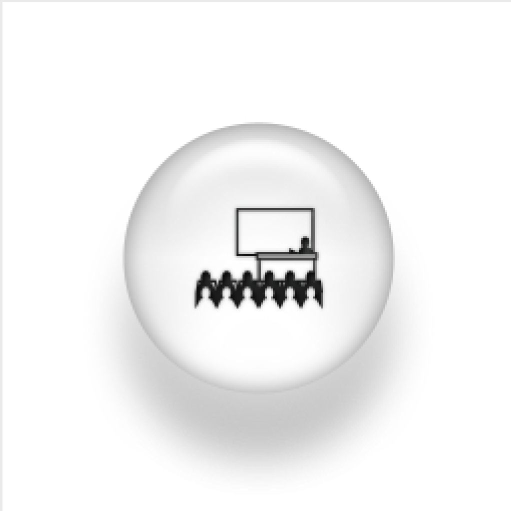
Lens-like particles and their entropy-driven clustering

Monday, 5th december 2011. 12:00-13:00



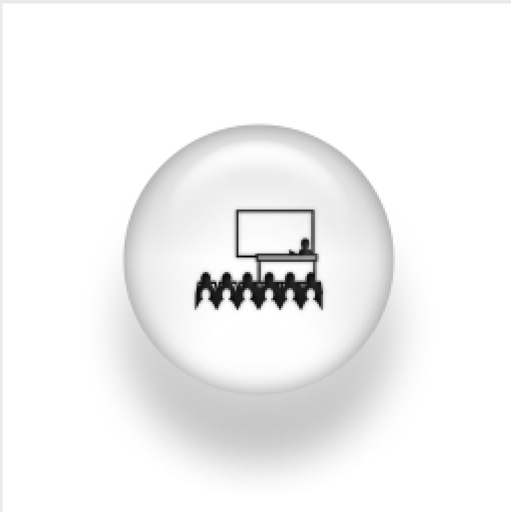
Giorgio Cinacchi
Departamento de Física Teórica de la Materia CondensadaUAM

ABSTRACT:
Suitable hard particle models are often sufficient to capture the basic features of the phase behaviour and properties of a variety of complex fluids. Onsager showed that a purely entropy driven isotropic-nematic phase transition occurs in systems of hard rods, while later it was also demonstrated that steric interactions suffice to give rise to smectic or columnar phases. In this talk, the phase behaviour of hard spherical caps is reported. By varying the sphere radius and constraining the area of the subtended surface to a fixed value, particles can be generated covering the entire interval from the hard platelet model to the hard sphere model. The particles belonging to the sub–interval delimited by the hard platelet and hard hemispherical surface models are infinitely thin and concave. This talk focuses on the low density phase behaviour of these curved particles. Spherical caps of sufficiently large radius of curvature, similar to platelets, exhibit a transition from the isotropic to the nematic phase on increasing pressure. By reducing the radius further, however, the latter phase is progressively

destabilized. For particles similar to lenses, in fact, the nematic phase is eventually replaced by a different type of self-assembly, characterized by the simultaneous aggregation of the centres of the parent spheres and the organization of the concave particles on the corresponding spherical surfaces. Lens-like particles thus exhibit a competition between a fluid-fluid phase transition and a clustering phenomenon, similar to what is observed in molecular systems forming micelles or colloidal suspensions forming cluster phases. For lens-like particles, however, this competition does not involve any energetic contribution: the phenomenology is purely entropy driven. For spherical caps similar to bowls, the clusters progressively change from being roundish to lacy. The relevance of all these simple model particles to a range of soft matter systems is discussed.

Josephson current in finite-length nanowire SNS junctions with Majorana fermions

Wednesday, 23 noviembre 2011. 12:00-13:00



Ramón Aguado
ICMM, CSIC
ABSTRACT:
The combination of strong spin-orbit effect with a Zeeman field may lead to the formation of helical electron liquids in single-channel semiconducting nanowires. When such an helical wire is contacted with an s-wave superconductor it is possible to induce a topological phase in which the system supports Majorana bound states (MBS) [1,2]. The Josephson current through junctions of these one-dimensional topological superconductors exhibits an anomalous 4π periodic phase (ϕ) dependence owing to the presence of MBS. Such a ‘fractional’ Josephson effect, which originates from a parity-protected level crossing of zero-energy MBS at $\phi=\pi$, is ubiquitous in systems supporting MBS [3,4,5] and provides an important experimental signature towards detecting MBS in a solid-state setting. To date, most of the theoretical studies have been restricted to either simplified models, such as Kitaev’s [2], or to infinite-

lenght superconducting junctions (except [6]). In this talk, I will discuss the Josephson effect in more realistic SNS junctions of arbitrary transparency and when both the normal and the nanowire regions are of finite length, namely beyond the short-junction and infinite topological superconductor limits. In general, the spectrum of Andreev bound states can become rather intricate and dense as opposed to the infinite-length case. Moreover, the low-energy spectrum around $\phi=\pi$ shows always anticrossings, originated from hybridization of four MBS, which may preclude the experimental observation of the fractional Josephson effect. At finite bias voltages, Landau-Zener dynamics involving the MBS and quasi-continuum Andreev levels gives rise to a nontrivial ac Josephson current. Interestingly, the ac current phase diagram as a function of the Josephson frequency/normal transmission shows regions of 4π periodicity which are tunable through bias/gate voltages [7].

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