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Aussois, France, 9-12 décembre.

Les organisateurs :

Fabien Portier et Robert Whitney

Secrétaire : *Marie-France Mariotto*

Responsable : *Bernard Plaçais*

Images on the cover

Color photo of Centre Paul Langevin. Website of Centre Paul Langevin.

TEM image of a measurment of conductance fluctuations in the mesoscopic metallic wire at the centre of the image. Guillaume Forestier, Cécile Naud and Laurent Saminadayar.

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Fabien Portier
Rob Whitney

Programme

Monday 9 December — afternoon

14:00 (Superconducting circuits 1) *Ioan Pop*
Coherent suppression of quasiparticle dissipation.

14:30 (Superconducting circuits 1) *Florent Lecocq*
Control and measurement of an optomechanical system using a superconducting qubit.

15:00 (Superconducting circuits 1) *Nicolas Roch*
Measurement induced entanglement between two remote superconducting qubits.

15:30 (Superconducting circuits 1) *Philippe Campagne-Ibarcq*
Measuring the interferences between past and future quantum states in the resonant fluorescence of a superconducting qubit.

16:00 — Coffee break —

16:30 (Superconducting circuits 1) *Manuel Houzet*
Inelastic microwave photon scattering off a quantum impurity in a Josephson-junction array.

17:00 (Cold atoms) *Arno Rauschenbeutel*
Nanofiber-based quantum interface for cold neutral atoms.

17:45 (Cold atoms) *Anna Minguzzi*
Optimal persistent currents for ultracold bosons stirred on a ring.

Tuesday 10 Dec — morning

9:00 (Edge-states) *Patrice Roche*
Quantum coherence of electrons injected above the Fermi sea.

9:30 (Edge-states) *Vincent Freulon*
Separation of neutral and charge modes in one dimensional chiral edge-states.

10:00 (Edge-states) *Claire Wahl*
Interactions and charge fractionalization in an electronic Hong-Ou-Mandel interferometer.

10:30 — Coffee break —

11:00 (Superconducting circuits 2) *Yuli Nazarov*
Quantum synchronization and transresistance quantization in superconducting devices.

11:30 (Superconducting circuits 2) *Frank Hekking*
Disordered Josephson junction chains: Anderson localization of normal modes and impedance fluctuations.

12:00 (Superconducting circuits 2) *Tristan Cren*
Vortex confinement and giant vortex states in nanoscale superconductors: a STM study.

Tuesday 10 Dec — afternoon

15:30 (Superconducting circuits 2) *Charis Quay*
Spin imbalance and spin-charge separation in a mesoscopic superconductor.

16:00 (Topological & Majorana) *Romain Giraud*
Quantum transport of spin-chiral Dirac fermions in Bi2Se3 nanostructures.

16:30 (Topological & Majorana) *Pierre Delplace*
Manipulation of Dirac points and Floquet topological transitions in a AC-driven honeycomb lattice.

17:00 — Coffee break —

17:30 (Topological & Majorana) *Alessandro Romito*
Scattering formula for the topological index of multichannel interacting wires.

18:00 (Topological & Majorana) *Cyril Petitjean*
Graphene Induced Topological Insulator.

18:30 (Topological & Majorana) *Marine Guigou*
Majorana Fermions in Graphene and Graphene-Like Materials.

21:00 — poster session (& bureau du GDR) —

Wednesday 11 Dec — morning

— time for discussion, sport or relaxation —

Wednesday 11 Dec — afternoon

16:00 (Graphene) *Romain Danneau*
Proximity induced superconductivity in clean bilayer graphene-boron nitride heterostructure weak links.

16:30 (Graphene) *Romain Maurand*
Ballistic Interference in suspended Graphene.

17:00 (Graphene) *Charlene Tonnoir*
Tunneling spectroscopy study of epitaxial graphene grown on superconducting rhenium.

17:30 — Coffee break —

18:00 (Graphene) *Fabrice Mortessagne*
From microwave resonators to artificial graphene.

18:30 (Graphene) *Guillaume Weick*
Dirac-like Plasmons in Honeycomb Lattices of Metallic Nanoparticles.

19:00 (Graphene) *Mark Goerbig*
Transitions magnéto-optiques dans une monocouche de disulphure de molybdène ou comment filtrer les électrons en spin et en vallée.

21:00 — poster session —

Thursday 12 Dec — morning

9:00 (Ultrafast & photons) *Benoit Gaury*
On the fate of ultra fast voltage pulses in quantum circuits.

9:30 (Ultrafast & photons) *Preden Roulleau*
Minimal-excitation states for electron quantum optics using levitons.

10:00 (Ultrafast & photons) *Jean-Jacques Greffet*
Cours : Physique mésoscopique du rayonnement de corps noir – part 1.

10:45 — Coffee break —

11:15 (Ultrafast & photons) *Jean-Jacques Greffet*
Cours : Physique mésoscopique du rayonnement de corps noir – part 2.

12:00 General discussion about GDR *led by Bernard Plaçais*

Thursday 12 Dec — afternoon

14:00 (Thermal) *Francesco Giazotto*
Coherent caloritronic nanocircuits based on the Josephson effect.

14:30 (Thermal) *Hervé Courtois*
Existence of an independent phonon bath in a quantum device.

15:00 (Thermal) *Sébastien Jézouin*
Quantum Limit of Heat Flow Across a Single Electronic Channel.

15:30 — Coffee break —

16:00 (local probes) *Stefan Heun*
Imaging fractional incompressible stripes in integer quantum Hall systems.

16:30 (local probes) *Boris Brun*
Wigner and Kondo physics in quantum point contacts revealed by scanning gate microscopy

17:00 (local probes) *Cosimo Gorini*
Weak probe scanning gate microscopy.

Poster Titles

Juan Manuel Aguiar Hualde.	New molecule for Long Lived light-induced charge separation states: A Combined Experimental/Ab-Initio study.
Alexandre Artaud.	Study of CVD-graphene on superconducting rhenium.
Erwann Bocquillon.	Spin pumping in topological insulators.
Riccardo Bosisio.	Thermoelecric conversion at the spectrum edges of disordered nanowires.
Edouard Boulat.	Exact results for out-of-equilibrium properties of integrable quantum impurity systems in their strong coupling regime.
Christophe Brun.	Proximity Effect between two Superconductors Spatially Resolved by Scanning Tunneling Spectroscopy.
Olivier Buisson.	Title to be announced.
Clémentine Carbillet.	Etude de la transition supraconducteur-isolant dans des films ultra-minces de NbN.
Denis Chevallier.	From Andreev bound states to Majorana fermions in topological wires on superconducting substrates : a story of mutation.
François Crépin.	Parity measurement in topological Josephson junctions.
David Dasenbrook.	Floquet theory of electron waiting times in quantum-coherent conductors.
Bastien Dassonneville.	Probing the dynamics of Andreev states in a coherent normal metal/superconducting ring: supercurrent fluctuations & spectroscopy of the minigap.
Raphaël de Gail.	Topologie et magnéto-transport dans les dérivés du graphène.
Raphaëlle Delagrange.	Competition between Kondo effect and superconductivity in a carbon nanotube based hybrid junction.
Pierre Devillard.	Waiting times for quantized pulses.
Eduard Driessen.	Electrodynamic response and local tunnelling spectroscopy of strongly disordered superconducting TiN films.
Clément Dutreix.	Friedel oscillations at the Dirac cone merging point in anisotropic graphene and graphenelike materials.
Andrey Fedorenko.	Effect of disorder on 2D topological merging transition from a Dirac semi-metal to a normal insulator.
Dario Ferraro.	Wigner function representation in electron quantum optics.
Michele Filippone.	The quantum RC-circuit: universal and giant charge dissipation in strongly correlated regimes.
Genevieve Fleury.	Scanning gate microscopy of Kondo dots: Fabry-Pérot interferences and thermally induced rings.
Jean-Noël Fuchs.	Mass and chirality inversion of a Dirac cone pair in Stueckelberg interferometry.
Çaglar Girit.	Spectroscopy of Andreev States.
Alexander Grimm.	Correlations of photons emitted by inelastic Cooper-pair tunneling.
Christoph Groth.	Kwant: a software package for quantum transport.
Daniel Hernangomez Perez.	Spectral Properties of Disordered Quantum Hall Systems with Rashba Spin-Orbit Coupling.
Benjamin Huard.	Quantum memory for microwave signals using superconducting circuits.
Camille Janvier.	Towards Andreev states manipulation.
Philippe Joyez.	Dynamical Coulomb blockade of the Josephson effect.

François Konschelle.	Effects of non-equilibrium noise on a quantum memory encoded in Majorana zero modes.
Norio Kumada.	Frequency and time domain measurements of edge magnetoplasmon in graphene.
Philippe Lafarge.	Quantum interference in molecular junctions.
Chuan Li.	Unipolar supercurrent through graphene grafted with Pt-Porphyrins: signature of gate voltage dependent magnetism.
Lih King Lim.	Scattering time in disordered gases.
Konstantin Nesterov.	Magnetic-field dependence of energy levels of superconducting nanoparticles with spin-orbit scattering.
Edmond Orignac.	Effect of disorder on 2D topological merging transition from a Dirac semi-metal to a normal insulator.
Olivier Parlavecchio.	Blocage de Coulomb du bruit et émission de photons non-classiques.
François D. Parmentier.	Tomonaga-Luttinger physics in electronic quantum circuits.
Frédéric Piechon.	From dia- to paramagnetic orbital susceptibility of Dirac cones.
Bernard Plaçais.	Klein tunnelling in a ballistic graphene transistor.
Wilfrid Poirier.	Quantum Hall effect in polycrystalline CVD graphene: grain boundaries impact.
Julien Renard.	Origins of nonlocality near the neutrality point in graphene.
Caroline Richard.	Signatures of triplet supercurrents in hybrid S/F structures.
Roman-Pascal Riwar.	Nonequilibrium fluctuation relations for adiabatically driven systems.
Benoît Roche.	Measuring the electric noise of a quantum switch.
Fernando Rojas.	Study of the hybrid entanglement between charge & oscillation modes & transport in a triple quantum dot shuttle: stationary & dynamic properties.
Chloé Rolland.	Transport quantique dans les nanofils InAs réalisés par épitaxie par jets moléculaires.
Ines Safi.	Nonlinear time-dependent transport in Tunnel junctions: Universal Relations.
Shamashis Sengupta.	Plasmon Mode Modifies the Elastic Response of a Nanoscale Charge Density Wave System.
Jean-René Souquet.	Dynamical Coulomb Blockade in an interacting 1D system coupled to an environment.
Doru Cristian Sticlet.	Persistent currents in Dirac-fermion rings.
René-Jean Tarento.	Title to be announced.
Nicolas Thiébaut.	Two-component fractional quantum Hall effect in the half-filled lowest Landau level in an asymmetric wide quantum well.
Candice Thomas.	Title to be announced.
Konrad Thomas.	Waiting time distributions for non-interacting fermions on a tight-binding chain.
Louis Veyrat.	Electrically tunable charge transport in CVD-grown nanostructures of Bi2Se3.
Benoît Voisin.	Quasi-1D quantum dots in silicon nanowires: singlet state and valley splitting.
Dietmar Weinmann.	Spin-orbit effects in nanowire-based wurtzite semiconductor quantum dots.
Robert Whitney.	The best quantum thermoelectric at finite power output.
Quentin Wilmart.	Klein tunnelling transistor in ballistic graphene.

TALK ABSTRACTS

(alphabetical order of speaker)

Boris Brun boris.brun@grenoble.cnrs.fr

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Wigner and Kondo physics in Quantum point contacts revealed by scanning gate microscopy.

What happens to electrons when confined to one dimension? Quantum Point Contacts (QPCs) give insights on how complex can be the answer to this simple question. As the width of a QPC increases, its conductance exhibits quantized steps in units of the conductance quantum, revealing the wave-like nature of electrons. However, deviations for this single-particle behavior have been observed since the very first realization of a QPC 25 years ago, witnessing the fundamental role of many-body effects in these simple devices. The most famous trademarks of electron interactions in QPCs are the 0.7 anomaly and the Zero Bias Anomaly (respectively a shoulder-like feature below the first plateau and a zero-bias peak in the differential conductance). To reveal the origin of these two intriguing signatures, we performed scanning gate microscopy (SGM) on a QPC at very low temperature. This advanced scanning probe technique consists in perturbating the system thanks to a negatively polarized tip while recording its conductance. We observe a spectacular oscillatory modulation of the 0.7 anomaly correlated with successive splittings of the ZBA when the tip approaches the QPC. We interpret this behavior as signatures of spontaneous localization occuring in the channel. An odd or even number of charges can localize depending on tip position, giving rise to single- or two-impurity Kondo effect. By performing self-consistent electrostatic simulations, we show that this localization is governed by a Wigner crystallization-like mechanism. These results shine a new light on the debated existence of interaction-induced localized states in QPCs (Iqbal et al., Nature (2013), Bauer et al., Nature (2013)). Moreover, this experiment shows once more how novel scanning probe techniques can be useful to investigate complex phenomena in nanostructures.

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Measuring the interferences between past and future quantum states in the resonant fluorescence of a superconducting qubit.

When an atom or substance is irradiated, it can reemit some radiation by fluorescence, a process in which the transition from excited to ground state produces a photon. For a two-level system irradiated at resonance, the Rabi oscillations between ground and excited states leave a footprint in the resonant fluorescence. This can be seen in the fluorescence spectral density by the appearance of the so-called Mollow triplet, which is made of two side peaks around resonance. In a quantum information

viewpoint, one may ask what information about the qubit is contained in the fluorescence. In order to answer this question optimally, one needs a system where both the qubit state and the fluorescence field can be measured in time. Superconducting qubits in cavity are fit for this task. We resonantly drove a superconducting qubit in a non-resonant cavity and measured the transmitted field as a function of time. Using the coupling between qubit and cavity it was also possible to measure whether the qubit was in ground or excited state at an arbitrary time. This experiment demonstrates how information about the qubit leaks out through fluorescence. In particular, the average values of the fluorescence measurement pre and post-selected on the qubit state exhibit non-classical weak values and perform a direct tomography of the non-hermitian field operator. This work provides a direct illustration of weak values in open systems which is perfectly explained by a recent theory.

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Existence of an independent phonon bath in a quantum device.

At low temperatures, the thermal wavelength of acoustic phonons in a metallic thin film on a substrate can widely exceed the film thickness. It is thus generally believed that a mesoscopic device operating at low temperature does not carry an individual phonon population. In this work, we provide direct experimental evidence for the thermal decoupling of phonons in a mesoscopic quantum device from its substrate phonon heat bath at a sub-Kelvin temperature. A simple heat balance model assuming an independent phonon bath following the usual electron-phonon and Kapitza coupling laws can account for all experimental observations.

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Vortex confinement and giant vortex states in nanoscale superconductors: a scanning tunneling microscopy study.

Tristan Cren, Lise Serrier-Garcia, Christophe Brun, François Debontridder and Dimitri Roditchev.

Superconductivity is characterized by two important length scales: the London penetration depth λ, and the coherence length ξ, the scale at which the superconducting order parameter varies. In this talk we show how the confinement of superconductivity to a scale comparable to ξ substantially modifies the superconducting properties. We choose a quasi-ideal model system: Pb islands deposited in-situ on the surface of Si(111). Depending on growth conditions, we are able to produce superconducting Pb-nano-crystals of various sizes and shapes, but also to reach the ultimate thickness limit with only a single atomic layer of Pb on Si(111). We studied the superconductivity in these artificial type II ($\xi \ll \lambda$) materials by Scanning Tunneling Spectroscopy in UHV at low temperatures down to 300mK, and under magnetic fields. We will show how vortices organize in nano-scale superconductors as function of field. In weekly confined systems (having the lateral size of the order of 10ξ or more), strong pinning effect are dominant at low fields, while at intermediate fields strong edge effects dominate and triangular lattice are recovered. At fields close to the critical field a so-called surface superconductivity is observed. In contrast, in strongly confined systems (having the lateral size $< 10\xi$), novel ultra-dense configurations, impossible in bulk superconductors, are observed. At even higher confinement we observed new quantum objects: the Giant Vortices characterized by a multiple winding number of the phase of the order parameter. We probed their unusual cores and found a good agreement [1] with the 45 year old theoretical prediction by D. Saint James. In the second part of the lecture we will present how the superconductivity evolves with reduction of Pb-film thickness down to a single atomic layer limit. For the ultimate atomic thickness, the electronic properties become extremely sensitive to the precise structure of the Pb/Si interface, single atomic surface steps or stacking faults disrupt the superconducting order. The sample becomes a nanometer-scale network of atomic superconducting terraces weakly connected by native Josephson links at steps and stacking faults.

[1] Cren, T., Serrier-Garcia L., D., Debontridder et al., Phys. Rev. Lett. 107, 097202 (2011)

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Proximity induced superconductivity in clean bilayer graphene-boron nitride heterostructure weak links.

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We report the study of a high quality bilayer graphene connected by superconducting electrodes and sandwiched between two hexagonal boron nitride layers used as both atomically flat substrate and gate dielectric. We show that this system does not remain superconducting around the charge neutrality point while a large critical current-normal resistance product is observed at high density. The presence of anomalous clear subgap features in the differential resistance which cannot be explained by the presence of multiple Andreev reflection is observed at every gate range. We show that both normal state resistance and supercurrent can be tuned by the displacement field created by the top and back gate. Additionally the IcRn product shows a linear dependence in charge carrier density which is expected for ballistic systems.

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Manipulation of Dirac points and Floquet topological transitions in a AC-driven honeycomb lattice.

The field of topological insulators has been recently significantly extended to periodically driven systems, namely, the Floquet topological insulators. In such systems, a trivial insulating phase can be tuned into an out-of-equilibrium topological insulating phase by a suitable a.c. driving, for instance, with an electromagnetic field. We investigate theoretically the effect of an in-plane a.c. electric field on a honeycomb lattice, (i.e. beyond the single Dirac cone approximation), and show that suitable high frequency drivings offer the possibility to move and annihilate (or create) a pair of Dirac points in the Floquet quasi-energy spectrum or to localize the electrons along specific directions [1]. When decreasing the frequency, the Floquet side bands couple and overlap, leading to various phases that can be switched in between by tuning the amplitude or the polarization of the electric field. For linear polarization, the system remains time-reversal symmetric, and the driving field gives rise to Dirac semimetallic phases with additional pairs of Dirac points in the band structure [1]. When time reversal symmetry is broken by non-linear polarizations, the system enters a topological insulating phase. In particular, the driving can generate a plateau structure for the Chern number, which povides an out-of-equilibrium analogue to the usual quantum Hall effect plateaux, but in the absence of magnetic field [2].

[1] Delplace, Gomez-Leon and Platero, arXiv:1304.6272, accepted to PRB.

[2] Gomez-Leon Delplace and Platero, arXiv:1309.5402

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Separation of neutral and charge modes in one dimensional chiral edge channels.

The propagation of electronic excitations along chiral quantum Hall edge channels has been thoroughly studied in the recent years in new electron optics experiments exploiting electron/photon analogies in this system. As examples, the electronic versions of Mach-Zehnder [1] or Hanbury Brown and Twiss [2] interferometers have been realized. However, contrary to photons, electrons interact with each other through the Coulomb interaction which strongly affects the coherence properties of electronic sources. In particular, at filling factor n=2, the dominant interaction mechanism results from the capacitive coupling between copropagating edge channels, as reported in Mach-Zehnder interferometers [3,4], and confirmed by energy relaxation measurements [5]. In this experiment, we investigate the coupling between two copropagating edge channels by measuring, in a wide frequency range going from 0.7 to 11 GHz, the transmission of charge density waves (or edge magnetoplasmons) from one edge to the other. A mesoscopic capacitor [6] is used to excite edge-magnetoplasmons of variable frequency, selectively in the outer channel and the resulting current in the inner channel is then collected after interaction on a length of a few microns. Damped charge oscillations between channels are observed, which can be explained by the existence of two eigenmodes of different velocities resulting from the interchannel coupling. The fast mode is a charge mode while the slow one is a neutral spin mode. Our experimental results are compared with theoretical models [7,8] providing a quantitative understanding of the coupling between the two edge channels and the resulting separation between the charge and neutral modes.

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[3] Roulleau, P., Portier, F., Roche, P., Cavanna, A., Faini, G., Gennser, U., Mailly, D., Physical Review Letters, 100(12) (2008).

[4] Neder, I., Heiblum, M., Levinson, Y., Mahalu, D., Umansky, V., Physical Review Letters 96(1) 016804 (2006).

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On the fate of ultra fast voltage pulses in quantum circuits.

As a general trend, nanoelectronics experiments are shifting toward frequencies in the GHz range and beyond. These frequencies are now becoming comparable to the internal characteristic time scales that set the quantum dynamics of the devices, resulting in new opportunities for studying the dynamical aspects of quantum mechanics. In this talk, we consider the condensed matter counterpart of the textbook Gedanken experiment of the “spreading of a wave packet”: the propagation of a voltage pulse in a mesoscopic system. The typical device is a Fabry-Perot cavity in a carbon nanotube, or a Mach-Zehnder interferometer in the quantum Hall regime. As the pulses get faster, we find the emergence of a new regime with striking physical signatures: fast pulses restore interference patterns even in the presence of large bias voltages; the total transmitted charge is not simply proportional to the total number of electrons sent, but oscillates with it. The resulting non-linear current characteristic $I = sin[aV_p\tau_p]$ (a = constant, V_p = pulse height, τ_p = pulse duration) is reminiscent of the Josephson relation while the system is non-superconducting.

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Coherent caloritronic nanocircuits based on the Josephson effect.

The Josephson effect [1] represents perhaps the prototype of macroscopic phase coherence and is at the basis of the most widespread interferometer, i.e., the superconducting quantum interference device (SQUID) [2]. Yet, in analogy to electric interference, Maki and Griffin [3] predicted in 1965 that thermal current flowing through a temperature-biased Josephson tunnel junction is a stationary periodic function of the quantum phase difference between the superconductors. The interplay between quasiparticles and Cooper pairs condensate is at the origin of such phase-dependent heat current, and is unique to Josephson junctions. In this scenario, a temperature-biased SQUID would allow heat currents to interfere [4, 5] thus implementing the thermal version of the electric Josephson interferometer. In this presentation we shall initially report the first experimental realization of a heat interferometer [6,7]. We investigate heat exchange between two normal metal electrodes kept at different temperatures and tunnel-coupled to each other through a thermal 'modulator' [5] in the form of a DC-SQUID. Heat transport in the system is found to be phase dependent, in agreement with the original prediction. Besides offering remarkable insight into thermal transport in Josephson junctions, our results represent a significant step toward phase-coherent mastering of heat in solid-state nanocircuits, and pave the way to the design of novel-concept coherent caloritronic devices, for instance, heat transistors, thermal splitters and diodes [8] which exploit phase-dependent heat transfer peculiar to the Josephson effect. In this latter context, we shall also present the concept for a further development of a Josephson heat interferometer based on a double superconducting loop [9] which allows, in principle, enhanced control over heat transport. We shall finally conclude presenting experimental results on the first prototypical quantum diffractor for thermal flux [10]. Specifically, thermal diffraction manifests itself with a peculiar modulation of the electron temperature in a small metallic electrode nearby-contacted to a Josephson junction when sweeping the magnetic flux Φ [11]. Remarkably, the observed temperature dependence exhibits Φ-symmetry and a clear reminiscence with a Fraunhofer-like modulation pattern, as expected fingerprints for a quantum diffraction phenomenon. Our results confirm a pristine prediction of quantum heat transport and, joined with double-junction heat interferometry demonstrated in [6], exemplify the complementary and conclusive proof of the existence of phase-dependent thermal currents in Josephson-coupled superconductors. This approach combined with well-known methods for phase-biasing superconducting circuits provides with a novel tool for mastering heat fluxes at the nanoscale.

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[11] M. J. Martnez-Pérez and F. Giazotto, arXiv:1310.0639 (submitted 2013)

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Quantum transport of spin-chiral Dirac fermions in Bi2Se3 nanostructures.

Recently discovered Z2 topological insulators (TIs) are ideally conducting at their interface only, where a gapless band structure forms. In a strong 3D TI, such as Bi2Se3, surface states are spin-chiral Dirac fermions with an odd number of Dirac cones. This property makes them robust against non-magnetic perturbations (topological protection due to a spin Berry phase), and the electrical transport of Dirac fermions can therefore be easily studied in nanostructures even in presence of a strong disorder. However, in real materials, the finite bulk conductivity often prevents the study of surface-state transport. We show that mesoscopic transport measurements can unambiguously reveal the specific properties of spin-chiral Dirac fermions in 3D TI [1]. The quantum conductance of a Bi2Se3 nanowire exhibits Aharonov-Bohm oscillations which result only from surface-state transport. At very low temperatures, the temperature dependence of their amplitude unveils the quasi-ballistic nature of charge transport, which is the signature of the weak coupling of quasi-particles to their environment. Our results further reveal the weak scattering by structural disorder, giving another evidence of the specific nature of spin-chiral Dirac fermions in a strong 3D TI.

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Transitions magnéto-optiques dans une monocouche de disulphure de molybdène ou comment filtrer les électrons en spin et en vallée.

La monocouche de disulphure de molybdène (MoS2) est un nouveau matériau de la classe des cristaux bi-dimensionnels dont le membre le plus connu est certainement le graphène. Alors que ce dernier est un conducteur un peu particulier où les électrons se comportent comme des fermions de Dirac sans masse, le MoS2 bi-dimensionnel est un semi-conducteur à gap direct. Des calculs ab initio ainsi que des modèles de liaisons fortes indiquent que les électrons dans ce matériaux sont également gouvernés par une équation de Dirac, mais cette fois-ci pour des fermions massifs. Contrairement à deux types de fermions de Schrdinger, pour des électrons dans la bande de conduction et pour des trous dans la bande de valence, les fermions de Dirac massifs révèlent des propriétés topologiques particulières dans la courbure de Berry associée [1]. La conséquence la plus remarquable s'observerait sous fort champ magnétique par l'émergence d'un niveau de Landau $n = 0$ dont la position en énergie dépend de la vallée mais qui ne disperse pas avec le champ. Alors qu'il est situé en haut de la bande de valence dans une vallée, il se trouve en bas de la bande de conduction dans l'autre. Les deux niveaux sont finalement séparés en deux branches par le couplage spin-orbite. Nous étudions théoriquement les transitions magnéto-optiques dans ce matériau, notamment celles qui font intervenir les niveaux $n = 0$. Dans le modèle de fermions de Dirac massifs sous champ magnétique, les transitions permises sont de type dipolaire, c'est-à-dire $(-1) \to 0$ et $0 \to 1$. La polarisation (circulaire) de la lumière permet de sonder les électrons d'une seule vallée, et comme la condition de résonance dépend de l'orientation de leur spin, la longueur d'onde de la lumière permet de filtrer une seule orientation du spin [2]. Finalement, nous étudions les corrections de bande au modèle de fermions de Dirac idéalisé. Elles donnent lieu à de nouvelles transitions permises au-delà des transitions dipolaires [2]. Notre théorie pourrait être testée par des expériences de spectroscopie d'absorption dans l'infra-rouge proche sous champ magnétique, qui s'est déjà révélée propice dans l'étude des niveaux de Landau du graphène.

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Weak probe scanning gate microscopy.

In scanning gate microscopy the transport through a nanostructure is measured while the charged tip of an atomic force microscope is scanned over the sample, locally pertubing it. Given the nonlocality of mesoscopic systems, is such a local probe capable of accessing local observables, such as the current density? And if so, under which conditions? Moreover, the presence of the probe modifies the symmetry of the nanostructure. Can one identify and characterize this effect? In order to answer such questions, a systematic theory of the conductance measurements of noninvasive (weak probe) scanning gate microscopy will be presented and specialized to the paradigmatic case of a quantum point contact.

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Cours : Physique mésoscopique du rayonnement de corps noir.

Le premier cours abordera tout d'abord les propriétés du rayonnement de corps noir au voisinage d'une interface. Nous montrerons que la densité d'énergie électromagnétique peut être supérieure à ce que prédit la loi de Planck de plusieurs ordres de grandeur. Nous montrerons aussi que cette densité d'énergie peut être quasi monochromatique. L'approche théorique qui permet de prédire ces résultats sera introduite qualitativement avant de passer à la présentation des expériences qui ont mis en évidence ces propriétés depuis un peu moins de dix ans. Le second cours portera sur le tranfert thermique radiatif à l'échelle du nanomètre. Une interprétation en termes de quantum de conduction thermique sera introduite. Enfin, nous discuterons de la possibilité de contrôler la cohérence du rayonnement de corps noir pour concevoir des sources IR incandescentes directionnelles, quasimonochromatiques et modulables à haute fréquence.

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Majorana Fermions in Graphene and Graphene-Like Materials.

We study the formation of Majorana fermions in graphene-like materials in the presence of a Zeeman eld, Rashba spin-orbit coupling, and in the proximity of an s-wave superconductor. We show that an exact mapping exists between an anisotropic graphene nanoribbon at $k = 0$ and a one-dimensional chain, for which the existence of Majorana fermions has been extensively discussed. Consequently we can predict the conditions for the emergence of Majorana fermions at the edges of such ribbon, and relate the existence of Majoranas to a band inversion in the bulk band structure. Moreover we nd that similar situations arise in isotropic graphene and we give some examples which show the formation of Majorana fermions in regular graphene.

C. Dutreix, M. Guigou, D. Chevallier, and C. Bena, arXiv:1309.1143 (2013).

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Disordered Josephson junction chains: Anderson localization of normal modes and impedance fluctuations.

D. M. Basko and F. W. J. Hekking Reference: Phys. Rev. B 88, 094507 (2013)

We study the properties of the normal modes of a chain of Josephson junctions in the simultaneous presence of disorder and absorption. We consider the superconducting regime of small phase fluctuations and focus on the case where the effects of disorder and absorption can be treated additively. We analyze the frequency shift and the localization length of the modes. We also calculate the distribution of the frequency-dependent impedance of the chain. The distribution is Gaussian if the localization length is long compared to the absorption length; it has a power law tail in the opposite limit.

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Imaging fractional incompressible stripes in integer quantum Hall systems.

Transport experiments provide conflicting evidence on the possible existence of fractional order within integer quantum Hall systems. In fact, integer edge states sometimes behave as monolithic objects with no inner structure, while other experiments clearly highlight the role of fractional substructures. Recently developed low-temperature scanning probe techniques offer today an opportunity for a deeper-than-ever investigation of spatial features of such edge systems. Here we use scanning gate microscopy (SGM) and demonstrate that fractional features were unambiguously observed in every integer quantum Hall constriction studied. Experiments were performed at bulk filling factor nu=1. We brought two counter-propagating integer-edge channels into proximity by means of a quantum point contact (QPC) and used the biased SGM tip to tune backscattering. Plateaus are observed in source-drain differential conductance maps whenever the tip induces an incompressible phase at the QPC center. We present SGM maps which directly reveal the width of the most relevant fractional incompressible stripes, corresponding to filling factors 1/3 and 2/5, together with their particle-hole conjugates 2/3 and 3/5. Our results compare well with predictions of the edge-reconstruction theory and may open up exciting developments. For instance, the ability to partition an integer edge and partially transmit one of its fractional components may be the key for the implementation of fractional quasi-particle Mach-Zehnder interferometers.

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Inelastic Microwave Photon Scattering off a Quantum Impurity in a Josephson-Junction Array.

We consider the propagation of microwave photons along an array of superconducting grains with a set of weakly-coupled grains at its center. Quantum fluctuations of charge on the weakly-coupled grains make the process of effective *photon splitting*. In such a process, an incoming photon may be split into a number of photons of lower energy. As an example, we consider a specific circuit allowing quantum fluctuations between two charge configurations of two weakly-coupled grains, thus mimicking the behavior of a Kondo impurity. We evaluate the elastic and inelastic photon scattering cross sections. These cross sections reveal many-body properties of the Kondo problem that are hard to access in its traditional fermionic version.

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Quantum Limit of Heat Flow Across a Single Electronic Channel.

Quantum physics sets a fundamental limit, called the conductance quantum, to the maximum electrical and thermal conduction across a single transport channel. In contrast to charge transport, the thermal conductance quantum G_Q is predicted to be independent of the type of particles carrying the heat. Such universality, combined with the relationship between heat and information, signals a general limit on information transfer. The thermal conductance quantum G_Q was previously measured for Bose particles, across the sixteen vibrational modes of narrow bridges. Here, we present the quantitative measurement of the quantum limited heat flow for Fermi particles and across a single electronic channel. Using noise thermometry and quantum point contacts in a 2D electron gas, we demonstrate an experimental agreement with the predicted value of G_Q at an accuracy better than 10%. This establishes experimentally this basic building block of quantum thermal transport and opens access to new experiments involving the quantum manipulation of heat.

S. Jezouin, F.D. Parmentier, A. Anthore, U. Gennser, A. Cavanna, Y. Jin and F. Pierre, Science, 03 October 2013 (10.1126/science.1241912)

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Control and measurement of an optomechanical system using a superconducting qubit.

In cavity optomechanics one can use photons to manipulate and measure the mechanical motion of a macroscopic object. With these techniques, ground state cooling of a mechanical resonator [1] and coherent transfer between a state of light and mechanical motion have been demonstrated [2]. So far these experiments have been using Gaussian resources, and therefore are limited to the observation of Gaussian states. I will discuss recent experiments that use an artificial atom as a non-linear resource for cavity optomechanics. The device consists of a superconducting phase qubit coupled to a lumped element microwave cavity, whose capacitance is formed by a mechanically compliant vacuum-gap capacitor. The motion of the mechanical resonator is encoded in the intra-cavity microwave field. The cavity can thus mediate an interaction between the qubit and the mechanical resonator, enabling preparation and readout of non-classical states of motion. In this talk I will show how we use the qubit to measure of the time evolution of the photon distribution in the microwave cavity, allowing us to infer the phonon distribution in the mechanical resonator.

[1] Teufel et al, Nature 475, 359 (2011)
[2] Palomaki et al, Nature 495, 210 (2013)

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Ballistic Interference in suspended Graphene.

The low-energy electronic excitations in graphene are described by massless Dirac fermions that have a linear dispersion relation. Taking advantage of this "optics-like" electron dynamics, generic optical elements like lenses and wave guides have been proposed for electrons in graphene. Tuning of these elements relies on the ability to adjust the carrier concentration in defined areas. However, the combination of ballistic transport and complex gating remains challenging. Here we report on the fabrication and characterization of suspended graphene p-n junctions. By local gating, resonant cavities can be defined, leading to complex Fabry-Pérot interferences. The observed conductance oscillations account for quantum interference of electrons propagating ballistically over distances exceeding 1micron. Visibility of the interferences is demonstrated to be enhanced by Klein collimation at the p-n interface. This finding paves the way to more complex gate-controlled ballistic graphene devices and brings electron optics in graphene closer to reality.

Peter Rickhaus, Romain Maurand, Ming-Hao Liu, Markus Weiss, Klaus Richter & Christian Schnenberger
Nature Communications 4, 2342 (2013)

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Optimal persistent currents for ultracold bosons stirred on a ring.

We study persistent currents for interacting bosons on a tight ring trap, subjected to an artificial gauge field induced by a rotating barrier potential. We show that at intermediate interactions the persistent current response is maximal, due to a subtle interplay of effects due to the barrier, the interaction and quantum fluctuations. These results are relevant for ongoing experiments with ultracold atomic gases on mesoscopic rings.

Ref: Marco Cominotti, Davide Rossini, Matteo Rizzi, Frank Hekking, Anna Minguzzi, arxiv:1310.0382

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From microwave resonators to artificial graphene.

Artificial graphene is an emerging field which offers a playground to investigate physical phenomena related to massless Dirac fermions in situations hardly reachable in genuine graphene. I will present recent results obtained in a photonic artificial graphene, working in the microwave range. The propagation of microwaves in an array of dielectric ceramic cylinders is well described by a tight-binding model taking into account up to third order nearest-neigbor couplings. Using a honeycomb lattice, the salient features of the graphene are observed and the influence of the second end third nearest-neigbor couplings are clearly identified. The high flexibility of the experimental setup allows to introduce anisotropy in the lattice. Thus, I will describe the observation of a topological transition between a gapless phase and a gapped phase in a strained graphene. Depending on the boundaries, armchair, zig-zag or bearded, the anisotropy leads to specific edge states I will present.

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Quantum synchronization and transresistance quantization in superconducting devices.

We show theoretically the possibility of quantum synchronization of Josephson and Bloch oscillations in a superconducting device. One needs an LC oscillator to achieve exponentially small rate of synchronization errors. The synchronization leads to quantization of transresistance similar to that in (Fractional) Quantum Hall Effect.

Alina Hriscu, Yuli V. Nazarov, Phys. Rev. Lett. 110, 097002 (2013)

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Graphene Induced Topological Insulator.

Two-dimensional topological insulators are commonly referred to as quantum spin-Hall (QSH) states. Contrary to the three-dimensional topological insulators that have been found to abound in nature, the two-dimensional are rather limited. However recently a spin-orbit induced QSH phase has been proposed. The key ingredient is the use of indium adatoms deposited on the surface of graphene thats should turn the latter into a QSH insulator characterized by a sizable gap. This artificial QSH system present strong potentials applications (thermopower, spintronics devices). One interesting fact about indiums is that the latter becomes superconductor at low enough temperature, Therefore the graphene+indium artificial QSH system becomes a promising candidate to study the competition between induced superconductivity and the spin-orbit coupling.
In this talk, we will first give a short introduction on the two-dimensional topological insulators and the related artificial QSH system. We then finally turn on the superconducting order and spin-orbit competition and show that starting form a general superconducing plaquette interaction, the latter can be reduced to a simpler effective model. This permit us to determine the first preliminary phase diagram.

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Coherent suppression of quasiparticle dissipation.

We demonstrate immunity to quasiparticle dissipation for a superconducting artificial atom. At the foundation of this protection rests a prediction of Brian Josephson from fifty years ago: the particle-hole interference of superconducting quasiparticles when tunneling across a Josephson junction. The Josephson junction under study is the central element of a fluxonium superconducting artificial atom, which we place in an extremely low loss environment and measure using radio-frequency dispersive techniques. When the fluxonium loop is biased around half a flux quantum, the quasiparticle dissipation channels coherently cancel and we observe a remarkable increase of the energy relaxation time. Precisely at the sweet spot we measure energy relaxation times exceeding one millisecond. Furthermore, by using a quantum amplifier (Josephson Parametric Converter) we can observe the dynamics of the quasiparticle population. This striking emergence of a quantum state which is protected against relaxation by symmetry is a rare and valuable asset in a generally fragile quantum world.

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Spin imbalance and spin-charge separation in a mesoscopic superconductor.

What happens to spin-polarised electrons when they enter a superconductor? Superconductors at equilibrium and at finite temperature contain both paired particles (of opposite spin) in the condensate phase as well as unpaired, spin-randomised quasiparticles. Injecting spin-polarised electrons into a superconductor thus creates both spin and charge imbalances [1-7] (respectively Q^* and S^*, cf. Ref. [4]). These must relax when the injection stops, but not necessarily over the same time (or length) scale as spin relaxation requires spin-dependent interactions while charge relaxation does not. These different relaxation times can be probed by creating a dynamic equilibrium between continuous injection and relaxation, which leads to constant-in-time spin and charge imbalances. These scale with their respective relaxation times and with the injection current. While charge imbalances in superconductors have been studied in great detail both theoretically [8] and experimentally [9], spin imbalances have not received much experimental attention [6, 10] despite intriguing theoretical predictions of spin-charge separation effects [11, 12]. These could occur e.g. if the spin relaxation time is longer than the charge relaxation time, i.e. Q^* relaxes faster than S^*. Fundamentally, spin-charge decoupling in superconductors is possible because the condensate acts as a particle reservoir [13, 11, 12]. We present evidence for an almost-chargeless spin imbalance in a mesoscopic superconductor. Our experiments yielded an estimate of the spin lifetime based on fits to theory: work is underway to determine the spin relaxation time independently and more directly, using frequency domain measurements.

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Nanofiber-Based Quantum Interface for Cold Neutral Atoms.

Abstract to be announced.

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Measurement induced entanglement between two remote superconducting qubits.

N. Roch, M. E. Schwartz, F. Motzoi, C. Macklin, R. Vijay, A. W. Eddins, A. N. Korotkov, B. Whaley, M. Sarovar, I. Siddiqi.

Measurement has traditionally been viewed as a mechanism for restoring classical behavior: a quantum superposition, once observed, transforms into a single classical state. However, for some quantum systems it is possible to design a measurement that probabilistically projects onto an entangled state, thereby purifying, rather than destroying, quantum correlations. We use a joint dispersive readout to entangle two superconducting qubits, in individual cavities, separated by more than a meter of coaxial cable. We obtain a concurrence of 0.35, which is consistent with transmission losses and detector efficiency. The intensity of the readout pulse can be continuously varied, enabling us to monitor the dynamics of entanglement generation. The data agree with both a Bayesian model and a full master equation treatment.

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Quantum coherence of electrons injected above the Fermi sea.

S. Tewari, P. Roulleau, F. Portier, U. Gennser, D. Mailly and P. Roche.

During the last decade, the edge states of the integer quantum hall regime have attracted significant attention as they give an unparalleled way to realize quantum optics like experiments with electrons. Since the first realisation of an electronic Mach-Zehnder interferometer in the integer quantum hall regime [1], the manipulation of edge states has been improved to such a point that the electronic counterpart of the Hong Ou Mandel has been realized with single electron sources [2], opening the way to more sophisticated experiments such as realizing the full quantum tomography of single electron sources. Implementing and analyzing these experiments will require the understanding of the quantum coherence of electrons injected above the Fermi sea. Here we explore this question by injecting electrons in a Mach-Zehnder interferometer at a given energy above the Fermi sea, using a Quantum Dot as an energy filter. We show that electrons injected above the Fermi sea have a remarkably long coherence length roughly independent of the energy up to 0.1 meV. The visibility of quantum interferences in the MZI is thus poorly affected by the energy at which electrons are injected, unlike the case when electrons are injected in a finite energy windows.

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Scattering formula for the topological index of multichannel interacting wires.

One-dimensional topological superconductors harbor Majorana bound states at their ends. These excitations obey non-abelian statistics and are a promising platform for error-free quantum computation. Signatures of their existence have been reported in experiments with a Zeeman field applied to a semiconductor wire with strong spin-orbit coupling in proximity to a s-wave superconductor. An index classifying the topological phases of 1d free fermionic systems can be obtained in terms of scattering matrix. It has been recently shown that interactions dramatically change the classification of topological phases in 1d. We present a scattering formula for the topological index of multi-channels interacting wires. Considering specifically the time reversal invariant (BDI) class, we identify the regimes where a unitary scattering matrix provides a valid topological index, and discuss the transitions between such regimes within the same topological phase. Finally, in the specific case of four-mode wires, we show how our scattering matrix approach allows to identify the nature of the edge state, which, in this case, takes the form of a Kondo-like cloud.

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Minimal-excitation states for electron quantum optics using levitons.

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The on-demand generation of pure quantum excitations is important for the operation of quantum systems, but it is particularly difficult for a system of fermions. This is because any perturbation affects all states below the Fermi energy, resulting in a complex superposition of particle and hole excitations. However, it was predicted nearly 20 years ago that a Lorentzian time-dependent potential with quantized flux generates a minimal excitation with only one particle and no hole. Here we report that such quasiparticles (hereafter termed levitons) can be generated on demand in a conductor by applying voltage pulses to a contact. Partitioning the excitations with an electronic beam splitter generates a current noise that we use to measure their number. Minimal-excitation states are observed for Lorentzian pulses, whereas for other pulse shapes there are significant contributions from holes. Further identification of levitons is provided in the energy domain with shot-noise spectroscopy, and in the time domain with electronic Hong-Ou-Mandel noise correlations. The latter, obtained by colliding synchronized levitons on a beam splitter, exemplifies the potential use of levitons for quantum information: using linear electron quantum optics in ballistic conductors, it is possible to imagine flying-qubit operation in which the Fermi statistics are exploited to entangle synchronized electrons emitted by distinct sources. Compared with electron sources based on quantum dots, the generation of levitons does not require delicate nanolithography, considerably simplifying the circuitry for scalability. Levitons are not limited to carrying a single charge, and so in a broader context n-particle levitons could find application in the study of full electron counting statistics. But they can also carry a fraction of charge when implemented in Luttinger liquids or in fractional quantum Hall edge channels; this allows the study of Abelian and non-Abelian quasiparticles in the time domain. Finally, the generation technique could be applied to cold atomic gases, leading to the possibility of atomic levitons.

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Tunneling spectroscopy study of epitaxial graphene grown on superconducting rhenium.

We report a new way to strongly couple graphene to a superconductor. The graphene monolayer has been grown directly on top of a superconducting Re(0001) thin film and characterized by scanning tunneling microscopy and spectroscopy. We observed a moiré pattern due to the mismatch between Re and graphene lattice parameters, that we have simulated with ab initio calculations. The density of states around the Fermi energy appears to be position dependent on this moiré pattern. Tunneling spectroscopy performed at 50 mK shows that the superconducting behavior of graphene on Re is well described by the Bardeen-Cooper-Schrieffer theory and stands for a very good interface between the graphene and its metallic substrate.

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Interactions and charge fractionalization in an electronic Hong-Ou-Mandel interferometer.

We consider an electronic analog of the Hong-Ou-Mandel interferometer, where two single electrons travel along opposite chiral edge states and collide at a Quantum Point Contact. Studying the current noise, we show that because of interactions between co-propagating edge states, the degree of indistinguishability between the two electron wavepackets is dramatically reduced, leading to reduced contrast for the HOM signal. This decoherence phenomenon strongly depends on the energy resolution of the packets. Insofar as interactions cause charge fractionalization, we show that charge and neutral modes interfere with each other, leading to satellite dips or peaks in the current noise. Our calculations explain recent experimental results where an electronic HOM signal with reduced contrast was observed.

C. Wahl, J. Rech, T. Jonckheere, and T. Martin, arXiv:1307.5257 (2013).

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Dirac-like Plasmons in Honeycomb Lattices of Metallic Nanoparticles.

We consider a two-dimensional honeycomb lattice of metallic nanoparticles, each supporting a localized surface plasmon, and study the quantum properties of the collective plasmons resulting from the near-field dipolar interaction between the nanoparticles. We analytically investigate the dispersion, the effective Hamiltonian, and the eigenstates of the collective plasmons for an arbitrary orientation of the individual dipole moments. When the polarization points close to the normal to the plane, the spectrum presents Dirac cones, similar to those present in the electronic band structure of graphene. We derive the effective Dirac Hamiltonian for the collective plasmons and show that the corresponding spinor eigenstates represent Dirac-like massless bosonic excitations that present similar effects to electrons in graphene, such as a nontrivial Berry phase and the absence of backscattering off smooth inhomogeneities. We further discuss how one can manipulate the Dirac points in the Brillouin zone and open a gap in the collective plasmon dispersion by modifying the polarization of the localized surface plasmons, paving the way for a fully tunable plasmonic analogue of graphene.

Ref: G. Weick, C. Woollacott, W. L. Barnes, O. Hess, and E. Mariani, Phys. Rev. Lett. 110, 106801 (2013).

POSTER ABSTRACTS

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New molecule for Long Lived light-induced charge separation states : A Combined Experimental/Ab-Initio study.

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Study of CVD-graphene on superconducting rhenium.

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Spin pumping in topological insulators.

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Topological insulators represent a new quantum state of matter, characterized by conducting Dirac surface (3D) or edge (2D) states while the bulk remains insulating. These properties originally stem from the topology of the bulk band structure. Using the peculiar inverted band structure of HgTe, both 3D and 2D topological insulators have been successfully implemented in (Hg,Cd)Te heterostructures, with the demonstration of quantum spin Hall effect [1] in narrow quantum wells, and quantum Hall effect [2] or induced superconductivity [3] in 3D structures. Beyond their exotic character, the Dirac topological states have helical spin polarization and thus offer the possibility to generate and manipulate spin currents in spintronics devices. In this regard, we present a project aiming at injecting spins, using the spin-pumping technique [4]. Under rf excitation, the magnetization of a ferromagnetic island precesses (ferromagnetic resonance). Via time-dependent exchange coupling, spins can then be pumped in a topological insulator underneath. Subsequent detection of spin and charge currents would bring new information on the expected helical spin polarization of topological states.

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Thermoelecric conversion at the spectrum edges of disordered nanowires.

The hard challenge to design thermoelectric devices with sufficiently high efficiencies could be overcome thanks to nanostructuration. Indeed nanostructural engineering provides opportunities to reduce the phonon thermal conductivity through appropriate boundary design and allows tailoring of the electronic band structure, a necessary condition to achieve large thermopowers. In comparison to their bulk counterparts, semiconductor nanowires have already led to improved thermoelectric conversion. In that context, it becomes important to determine the doping level of nanowires that optimizes the thermoelectric efficiency. Recent experimental measurements carried out by P. Kim et al [1] illustrates the growing interest of the community to that issue. In this work [2], we study thermoelectric conversion in a non-interacting disordered nanowire, in presence of a gate voltage which allows to modify the carrier density in it. We discuss the relevant temperature scales which identify the different transport mechanisms. We focus on two situations: first, a low-T (coherent) regime in which transport through the system is elastic; secondly, a higher-T regime known as Mott's Variable Range Hopping (VRH) in which transport is accomplished via inelastic phonon-assisted hopping. In both cases, we investigate how the typical thermopower and its mesoscopic fluctuations depend on the external gate voltage, and show that thermoelectric conversion is enhanced when the edges of the energy spectrum of the system are probed. Using a previous work of Derrida and Gardner giving the localization length of the Anderson model near the spectrum edges [3], we derive for the low-T case an analytical formula describing perfectly the behaviour of the typical thermopower as a function of the gate-voltage.

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Exact results for out-of-equilibrium properties of integrable quantum impurity systems in their strong coupling regime.

Quantum impurity models can be very naturally driven out-of-equilibrium, by connecting them to several baths in different equilibrium states, as realized e.g. in some 2DEG devices. The description of the steady state resulting from biasing the baths is still an open problem in the generic case where interactions are present. In the case of integrable impurity models, it turns out that the exact solution *in equilibrium* cannot be straightforwardly extended to describe the out-of-equilibrium properties. In this talk, I will show that integrability nevertheless sometimes allows for an exact and systematic expansion in the bias, at arbitrary order, that is also valid to describe dynamical forcing. Our approach can be viewed as a generalization of the Sommerfeld expansion to the interacting case. This method will be applied to the specific example of the interacting resonant level model, where electrical and thermal currents are computed for AC forcing. I shall also discuss the extension of our work to the exact treatment of the Kondo problem out-of-equilibrium.

Ref.: L. Freton and E. Boulat, arXiv/1303.7441

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Proximity Effect between two Superconductors Spatially Resolved by Scanning Tunneling Spectroscopy.

We present a combined experimental and theoretical study of the proximity effect in an atomic scale controlled junction between two different superconductors. Elaborated on a Si(111) surface, the junction comprises a Pb nanocrystal with an energy gap Delta1 = 1.2 meV, connected to a crystalline atomic monolayer of lead with Delta2 = 0.23 meV. Using in situ scanning tunneling spectroscopy we probe the local density of states of this hybrid system both in space and in energy, at temperatures below and above the critical temperature of the superconducting monolayer. Direct and inverse proximity effects are revealed with high resolution. Our observations are precisely explained with the help of a self-consistent solution of the Usadel equations. Our results demonstrate that in the vicinity of the Pb islands, the Pb monolayer locally develops a finite proximity-induced superconducting order parameter, well above its own bulk critical temperature.

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Title to be announced.

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Etude de la transition supraconducteur-isolant dans des films ultra-minces de NbN.

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From Andreev bound states to Majorana fermions in topological wires on superconducting substrates : a story of mutation.

We study the proximity effect in a topological nanowire tunnel coupled to an s-wave superconducting substrate. We use a general Green's function approach that allows us to study the evolution of the Andreev bound states in the wire into Majorana fermions. We show that the strength of the tunnel coupling induces a topological transition in which the Majorana fermionic states can be destroyed when the coupling is very strong. Moreover, we provide a phenomenologial study of the effects of disorder in the superconductor on the formation of Majorana fermions. We note a non-trivial effect of a quasiparticle broadening term which can take the wire from a topological into a non-topological phase in certain ranges of parameters. Our results have also direct consequences for a nanowire coupled to an inhomogenous superconductor.

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Parity measurement in topological Josephson junctions.

We study the properties of a topological Josephson junction made of both edges of a 2D topological insulator. We show that, due to fermion parity pumping across the bulk, the global parity of the junction has a clear signature in the periodicity and critical value of the Josephson current. In particular, we find that the periodicity with the flux changes from 4 *pi* in a junction with an even number of quasi-particles to 2π in the odd sector. In the case of long junctions, we exhibit a rigorous mathematical connection between the spectrum of Andreev bound-states and the fermion parity anomaly, through bosonization. Additionally, we discuss the rather quantitative effects of Coulomb interactions on the Josephson current.

Francois Crepin and Bjoern Trauzettel, arXiv:1305.7433.

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Floquet Theory of Electron Waiting Times in Quantum-Coherent Conductors.

We present a Floquet scattering theory of electron waiting time distributions in periodically driven quantum conductors. We employ a second-quantized formulation that allows us to relate the waiting time distribution to the Floquet scattering matrix of the system. As an application we evaluate the electron waiting time for a periodically driven quantum point contact. A sequence of Lorentzian-shaped voltage pulses generates a train of levitons whose waiting time distribution is investigated. In addition we periodically modulate the transmission of the quantum point contact and find clear fingerprints in the electron waiting times. The distributions of waiting times provide us with a detailed characterization of the dynamical properties of the quantum-coherent conductor.

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Probing the Dynamics of Andreev States in a Coherent Normal metal/Superconducting ring: Supercurrent Fluctuations & Spectroscopy of the Minigap.

Most properties of a non superconducting (N) metal connected to two superconductors (a SNS junction) can be seen as resulting from the phase dependent Andreev states (AS) in N. The density of states in N is then drastically changed with the emergence of a small energy gap, the minigap. Whereas AS equilibrium properties are well understood, their dynamics is a more complex issue[1]. We perform experiments on a phase (ϕ) biased NS ring coupled to a superconducting resonator. The modification of the resonances (f from 200 MHz up to 14 GHz) yields the complex phase dependent susceptibility $\partial_\phi I_{ring} = \chi(f, \phi) = \chi' + i\chi''$. As expected, we find a non-dissipative χ' related to the supercurrent flowing through the ring thus revealing the Current-Phase relation. A more striking finding[2] is the existence of a dissipative χ'' revealing a noisy supercurrent, predicted[3] but never observed before. According to our analysis of the experiment[4], χ"" could also reveal the structure of the minigap in a regime of low temperature and high frequency not yet accessed experimentally. Moreover, as f increases we show that the main dissipation mechanism changes from population relaxation to microwave-induced transitions across the minigap. These results show that such ac measurements in a wide range of frequency, close to equilibrium , reveal physical properties of SNS junctions that are not accessible by standard transport measurements. Such measurements are uniquely suited to investigate more exotic systems, for instance with the normal diffusive wire replaced by a semiconducting nanowire with strong spin orbit interactions.

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Topologie et magnéto-transport dans les dérivés du graphène.

On présente une théorie générale permettant de comprendre la dynamique des électrons de type Dirac, qu'on peut rencontrer dans le graphène et ses dérivés, sous fort champ magnétique, [3]. La présence d'un niveau de Landau à énergie nulle peut notamment s'interpréter comme une propriété topologique forte et ainsi résistante aux perturbations. Le reste des niveaux est, lui, très bien retranscrit par les analyses semi-classiques. Cette compréhension des niveaux de Landau est essentielle pour comprendre les spectres expérimentaux, accessibles par des mesures de transports de type barre de Hall. La théorie que nous développons permet ainsi de rendre compte des expériences dans la bicouche de graphène

sous diverses contraintes [1,2]. Nous introduisons ici, de manière pédagogique, l'essentiel de la théorie qui permet une lecture claire des spectres en questions.

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Competition between Kondo effect and superconductivity in a carbon nanotube based hybrid junction.

We study the supercurrent of an hybrid junction superconductor/carbon nanotube (CNT)/superconductor. We are interested in a regime where the coupling between electrodes and nanotube is weak enough to consider the carbon nanotube as a quantum dot. Thanks to this, for an odd number of charges in the dot, we observe Kondo effect with a characteristic energy ($k_B T_k$) of the same order as the superconducting gap (Δ) of the Pd/Al contacts used. This junction is put into a superconducting quantum interference device (SQUID), as well as two tunnel junctions with far higher critical current. Measuring the critical current of this very asymmetric SQUID with respect to the magnetic flux applied, we have access to the current-phase relation of the hybrid junction, which teaches us about the interplay between the Kondo effect and the superconductivity induced in the CNT. Indeed, it permits us to measure a transition from a 0 to a π-junction for fixed odd parity and superconducting gap Δ, varying only the value of T_k. We also try to measure the current-phase relation at the transition, in order to compare it with theoretical predictions.

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Waiting times for quantized pulses.

The distribution $W(\tau)$ of waiting times for quantized Levitov pulses of width ξ impinging on a quantum point constact (QPC) of variable transmission is studied both in the weak and in the strong overlapping regime. In the last regime, $W(\tau)$ is roughly exponentially decaying at large times with characteristic time proportional to ξ, but with weak oscillations of "period" $\xi/2v_F$, with v_F the Fermi velocity. These are the equivalent of h/eV for a QPC subjected to a constant bias voltage V. Even for perfect transmission, the distribution is never Gaussian[2], contrary to what happens for a QPC at constant V and zero temperature[1].

[1] M. Albert, G. Haack, C. Flindt, and M. Büttiker, Phys. Rev. Lett. 108, 186806 (2012).
[2] M. Albert and P. Devillard, in preparation (2013).

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Electrodynamic response and local tunnelling spectroscopy of strongly disordered superconducting TiN films.

We have studied the electrodynamic response of strongly disordered superconducting TiN films using microwave resonators, where the disordered superconductor is the resonating element in a high- quality superconducting environment of NbTiN. We describe the response assuming an effective pair-breaking mechanism modifying the density of states, and compare this to local tunnelling spectra obtained using scanning tunnelling spectroscopy. For the least disordered film ($k_F l = 8.7$, $R_s = 13$ ohm), we find good agreement, whereas for the most disordered film ($k_F l = 0.82, R_s = 4.3$ kohm), there is a strong discrepancy, which signals the breakdown of a model based on uniform properties.

Preprint available: http://arxiv.org/abs/1310.3176.

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Friedel oscillations at the Dirac cone merging point in anisotropic graphene and graphene-like materials.

Anisotropies in graphenelike materials may make the two inequivalent Dirac cones merge at time-reversal invariant points of the Brillouin zone. This merging defines a topological transition between a semimetallic phase and a band insulator. The introduction of a single impurity in such systems involves Friedel oscillations in the local density of states. On the one hand, the spatial dependence of the impurity state wave function exhibits a power-law decay with the distance from the impurity in the semimetallic phase, whereas it presents an exponential decay in the gapped phase. On the other hand, the semi-Dirac spectrum near the merging point induces a change in the decay laws in the Friedel oscillations, from an inverse-square law in the semi-metallic phase, to an inverse-linear law exactly at the transition. At low energies this provides a real-space signature of the topological transition (published work: Phys. Rev. B 87, 245413 (2013), Clément Dutreix, Liviu Bilteanu, Anu Jagannathan, and Cristina Bena).

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Effect of disorder on 2D topological merging transition from a Dirac semi-metal to a normal insulator.

We study the influence of disorder on the topological transition from a two-dimensional Dirac semi-metal to an insulating state. This transition is described as a continuous merging of two Dirac points leading to a semi-Dirac spectrum at the critical point [1]. The latter is characterized by a dispersion relation linear in one direction and quadratic in the orthogonal one. Recently such a merging of tunable Dirac points has been realized using a degenerate Fermi gas trapped in a 2D honeycomb optical lattice [2], in photonic graphene [3] and in microwave experiments [4]. Using the self-consistent Born approximation and renormalization group we calculate the density of states above, below and in the vicinity of the transition in the presence of different types of disorder. Beyond the expected disorder smearing of the transition we find an intermediate disordered semi-Dirac phase. On one side this phase is separated from the insulating state by a continuous transition while on the other side it evolves through a crossover to the disordered Dirac phase [5].

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Wigner function representation in electron quantum optics.

A time-frequency description of the electron coherence will be presented in analogy with the Wigner function representation in quantum mechanics. This approach reveals extremely useful in order to encode in a unique real function both the coherence properties in the time domain and the nature of the excitation generated by single or few electron sources. When these sources are used as inputs of a Mach-Zehnder interferometer, the quantum interferences emerge in an clear way in this representation. From the knowledge of the Wigner function and in particular of its marginal distribution one derives the evolution of the mean current as a function of time as well as the energy spectrum that are affected in a complementary way by the interference. The effects of interaction with the external environment will be discussed for different injected electronic wave-packet, commenting about their robustness against decoherence and relaxation.

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The quantum RC-circuit: universal and giant charge dissipation in strongly correlated regimes.

The quantum coherence effects between electrons in nanodevices lead to a rich variety of phenomena in quantum transport. One of these is the violation of Kirchhoff's laws in the quantum RC-circuit. In this system, a metallic lead exchanges electrons coherently with a quantum dot driven out of equilibrium by a top metallic gate. In the non interacting case, the charge relaxation resistance of the system differs from the usual dc-transport resistance given by the Landauer formula. The charge relaxation resistance is universally fixed to $h/(2e^2)$ for a single mode conductor, regardless of the transmission of the mode. We show that the Fermi liquid behavior of these systems at low energy explains this universality even in the presence of strong interactions in the dot. Moreover, we discuss the emergence of a giant dissipation regime associated to the breaking of the Kondo singlet for Zeeman energies of the order of the Kondo temperature. We provide a comprehensive analytic description of the peak of the charge relaxation resistance associated to this giant dissipation and demonstrate its persistence out of the Kondo regime.

Filippone M., Le Hur K., Mora C. : Admittance of the SU(2) and SU(4) Anderson quantum RC circuits, Physical Review B 88, 045302 (2013).
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Scanning gate microscopy of Kondo dots: Fabry-Pérot interferences and thermally induced rings.

We study the conductance g of an electron interferometer formed in a two dimensional electron gas between a nanostructured quantum contact and the charged tip of a scanning gate microscope. In addition to Fabry-Pérot interference fringes spaced by half the Fermi wavelength, interference rings may be seen in the images giving g as a function of the tip position [1]. This occurs if the contact transmission has at least two resonances. Opening the contact in the middle of these resonances at temperatures of the order of their spacing, interference rings are induced by a beating effect between the contributions of each resonances to g. The ring spacing is given as a function of the resonance spacing. This beating effect is illustrated taking for the contact a quantum dot opened in the middle of a Kondo valley above the Kondo temperature.

[1] A. Kleshchonok, G. Fleury, G. Lemarié and J.-L. Pichard, arXiv:1305.0106 (2013).

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Mass and chirality inversion of a Dirac cone pair in Stueckelberg interferometry.

The aim of the present work is to show that a Stueckelberg interferometer made of two massive Dirac cones can reveal information on band eigenstates such as the chirality and mass sign of the cones. For a given spectrum featuring two gapped cones, we propose several low-energy Hamiltonians differing by their eigenstates properties. The corresponding inter-band transition probability is affected by such differences in its interference fringes being shifted by a new phase of geometrical origin. This phase can be a useful bulk probe for cold atoms in topological optical lattices.

L.K. Lim, J.N. Fuchs and G. Montambaux, arXiv:1308.0281.

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Spectroscopy of Andreev States.

The microscopic theory of superconducting weak links states that the Josephson current is associated to discrete, spin-degenerate Andreev levels. These levels, which have energies inside the bulk superconducting gap, can be populated by quasiparticles localized at the weak link. A single quasiparticle can suppress completely the Josephson supercurrent in one conduction channel; two quasiparticles can reverse it. Here we describe experiments which directly probe the quasiparticle excitation spectrum of Andreev levels in superconducting atomic contacts. We excite single quasiparticles with an on-chip microwave source and measure all possible transitions between Andreev states using two complementary techniques: absorption spectroscopy [1] and supercurrent spectroscopy [2].

[1] L. Bretheau, Ç. Girit et al, Nature 499, 312 (2013).
[2] L. Bretheau et al, submitted (2013).

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Correlations of photons emitted by inelastic Cooper-pair tunneling.

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Kwant: a software package for quantum transport.

Christoph W. Groth, Michael Wimmer, Anton R. Akhmerov, Xavier Waintal, arXiv:1309.2926.

In this talk, I will introduce Kwant, a new code for numerical calculations on tight-binding models with a strong focus on quantum transport. Some applications of Kwant from recent research will be shown as well. Kwant has been designed to be efficient in terms of the *human* time needed to perform challenging quantum transport computations. The flexibility and ease-of-use necessary for this goal were achieved by exposing the natural concepts of the theory of quantum transport (lattices, symmetries, electrodes, orbital/spin/electron-hole degrees of freedom) directly in Python, a powerful yet easy-to-learn programming language that is gaining more and more popularity with scientists. Thus, in contrast to many monolithic scientific software packages, no traditional input files are used with Kwant. Instead, one writes short programs that define a system and calculate its quantum properties using facilities jointly provided by Python and Kwant. Thanks to this approach, other functionality provided by the thriving scientific Python community can be used easily as well. Out-of-the-box, Kwant supports the calculation of transport properties (conductance, noise, scattering matrix), dispersion relations, modes, wave functions, various Green's functions, and out-of-equilibrium local quantities. Other computations involving tight-binding Hamiltonians can be implemented easily. Kwant is also efficient in terms of *computer* time: thanks to the use of innovative algorithms, it is often faster than other available codes, even those entirely written in the low level FORTRAN and C/C++ languages. Kwant is free software available at http://kwant-project.org/.

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Spectral Properties of Disordered Quantum Hall Systems with Rashba Spin-Orbit Coupling.

We theoretically investigate the spectral properties and the spatial dependence of the local density of states (LDoS) in disordered two-dimensional electron gases (2DEG) in the quantum Hall regime, taking into account the combined presence of electrostatic disorder, random Rashba spin-orbit (SO) interaction and finite Zeeman coupling. To this purpose, we extend a semicoherent-state Green's function formalism well-suited to describe spinless 2DEG under magnetic fields in the presence of smooth arbitrary disorder, that here incorporates the non-trivial coupling between the orbital and spin degree of freedom into the electronic drift states. The technique allows us to derive analytical and controlled non-perturbative expressions of the energy spectrum in arbitrary locally flat disorder potentials with random electric fields and fluctuating Rashba SO coupling. As an illustration of the present theory, we obtain analytical microscopic expressions for the LDoS in different temperature regimes which can be used as a starting point to interpret scanning tunneling spectroscopy data at high magnetic fields. In this context, we study the spatial dependence and linewidth of the LDoS peaks and explain an experimentally-noticed correlation between the spatial dispersion of the SO splitting and the local extrema of the potential energy landscape.

Daniel Hernangomez-Perez, Jascha Ulrich, Serge Florens and Thierry Champel Réf. arXiv:1309.6977.

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Quantum memory for microwave signals using superconducting circuits.

Quantum memories are key elements for quantum communication and quantum computing. We have realized a superconducting circuit able to realize a memory for non-classical microwave states. In conversion mode, the circuit can tune dynamically the coupling between a well isolated microwave cavity and a transmission line. In amplification mode, it can generate entanglement between a mode of the cavity and a propagating mode on the transmission line. We demonstrate how this circuit works and test its storage and writing times. The storage efficiency reaches as much as 80%. Besides, we were able to demonstrate entanglement between the memory and the propagating mode. This paves the way to several applications like teleporting a microwave cat or entanglement of qubits on a distance by entanglement transfer.

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Towards Andreev states manipulation.

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Dynamical Coulomb blockade of the Josephson effect.

The $P(E)$ theory is well known to accurately describe the interaction of a nonsuperconducting tunnel junction with its environment. We extend $P(E)$ theory to the case of superconducting junctions. This yields the finite-frequency dynamics of this interacting system and allows to better apprehend the range of usability of the standard Josephson Hamiltonian.

Ref: Philippe Joyez, Phys. Rev. Lett. 110, 217003 (2013).

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Effects of non-equilibrium noise on a quantum memory encoded in Majorana zero modes.

In order to increase the coherence time of topological quantum memories in systems with Majorana zero modes, it has recently been proposed to encode the logical qubit states in non-local Majorana operators which are immune to localized excitations involving the unpaired Majorana modes. In this encoding, a logical error only happens when the quasi-particles, subsequent to their excitation, travel a distance of the order of the spacing between the Majorana modes. Here, we study the decay time of a quantum memory encoded in a clean topological nanowire interacting with an environment with a particular emphasis on the propagation of the quasi-particles above the gap. We show that the non-local encoding does not provide a significantly longer coherence time than the local encoding. In particular, the characteristic speed of propagation is of the order of the Fermi velocity of the nanowire and not given by the much slower group velocity of quasi-particles which are excited just above the gap.

See also: F. Konschelle and F. Hassler. Effects of nonequilibrium noise on a quantum memory encoded in Majorana zero modes. Phys. Rev. B, 88 p.075431 (2013). arXiv:1306.2519.

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Frequency and time domain measurements of edge magnetoplasmon in graphene.

We investigate proparties of a cavity of edge magnetoplasmons (EMPs) formed in graphene by frequency and time domain measurements. We obtained resonance frequency of the fundamental mode and some harmonics. We will show the dispersion relation and the decay rate of EMPs.

Related works: N. Kumada et al., Nature Commun. 4, 1363 (2013) and I. Petkovi et al., Phys. Rev. Lett. 110, 016801 (2013).

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Quantum interference in molecular junctions.

Quantum interference due to the wave nature of electrons is a well-known quantum effect in mesoscopic physics. As in mesoscopic systems, there is a deep relationship between the structure of a molecule and its quantum transport properties: cross-conjugated molecules are the chemical compound that can act as molecular quantum interferometers. We have investigated quantum interference in cross-conjugated molecules embedded in solid state devices by direct current-voltage and differential conductance transport measurements of anthraquinone-based large area planar junctions. A temperature analysis of the conductance curves revealed that electron-phonon coupling is the principal decoherence mechanism causing large conductance oscillations at low temperature.

V. Rabache, J. Chaste, P. Petit, M. L. Della Rocca, P. Martin, J.-C. Lacroix, R. L. McCreery, and P. Lafarge, J. Am. Chem. Soc. 135, 10218 (2013).

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Unipolar supercurrent through graphene grafted with Pt-Porphyrins: Signature of gate voltage dependent magnetism.

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Inducing magnetism in graphene holds great promises, such as new exotic magnetic phases, or the control of exchange interaction via a gate electrode. In the present work, we have grafted graphene with Pt-porphyrin molecules which interact with graphene's delocalized electrons. Neutral Pt-porphyrins are non-magnetic, but the ionized form carriers a magnetic moment of roughly one Bohr magneton. At room temperature we find that the molecules electron-dope the graphene and there is a hysteresis in gate voltage, demonstrating that electron transfer occurs. More surprisingly, the grafted graphene's mobility increases. At low temperature, we show how superconducting contact electrodes can uniquely reveal the magnetic order induced in a mesoscopic, one micron-long graphene sheet. The unipolar nature of the induced supercurrent, which is enchanced at negative gate voltage but suppressed at positive gate voltage, may be the evidence for the Fermi-level controlled exchange interaction between localized spins and graphene. We will compare these findings to experiments with non-superconducting electrodes.

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Scattering time in disordered gases.

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Magnetic-field dependence of energy levels of superconducting nanoparticles with spin-orbit scattering.

We study the response of discrete energy levels of ultrasmall metallic grains to an external magnetic field in the presence of both spin-orbit scattering and superconducting correlations. We concentrate on the linear and quadratic in magnetic field corrections to energies, which are parametrized, respectively, by g-factors and level curvatures. Both corrections fluctuate from level to level in the presence of spin-orbit scattering. We show that the distribution of fluctuating g-factors is not affected by pairing correlations, while the distribution of level curvatures is sensitive to them even in the smallest grains, in which the mean single-particle level spacing is greater than the pairing gap. Therefore, level curvatures are a good tool to detect pairing correlations in tunneling spectroscopy experiments.

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Effect of disorder on 2D topological merging transition from a Dirac semi-metal to a normal insulator.

We study the influence of disorder on the continuous merging of two Dirac points. Using the self-consistent Born approximation and the renormalization group we obtain the density of states above, below and in the vicinity of the transition in the presence of random potential, random Dirac mass and random gauge disorder. We find an intermediate disordered semi-Dirac phase separated from the insulating state by a continuous transition but continuously connected to the random Dirac phase by a crossover.

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Blocage de Coulomb du bruit et émission de photons non-classiques.

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Tomonaga-Luttinger physics in electronic quantum circuits.

In one-dimensional conductors, interactions result in correlated electronic systems. At low energy, a hallmark signature of the so-called Tomonaga-Luttinger liquids is the universal conductance curve predicted in presence of an impurity. A seemingly different topic is the quantum laws of electricity, when distinct quantum conductors are assembled in a circuit. In particular, the conductances are suppressed at low energy, a phenomenon called dynamical Coulomb blockade. Here we investigate the conductance of mesoscopic circuits constituted by a short single-channel quantum conductor in series with a resistance, and demonstrate a proposed link to Tomonaga-Luttinger physics. We reformulate and establish experimentally a recently derived phenomenological expression for the conductance using a wide range of circuits, including carbon nanotube data obtained elsewhere. By confronting both conductance data and phenomenological expression with the universal Tomonaga-Luttinger conductance curve, we demonstrate experimentally the predicted mapping between dynamical Coulomb blockade and the transport across a Tomonaga-Luttinger liquid with an impurity.

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From dia- to paramagnetic orbital susceptibility of Dirac cones.

We study the orbital susceptibility of coupled energy bands with a pair of Dirac points, as in graphene. We show that different systems having the *same* zero-field energy spectrum exhibit strong differences in their orbital magnetic response at zero energy, ranging from diamagnetism (graphene) to paramagnetism (dice lattice). A lattice model is introduced which interpolates continuously between these two limits. This striking behavior is related to a Berry phase varying continuously from π to 0. These predictions could be tested with cold atoms in an optical lattice.

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Klein tunnelling in a ballistic graphene transistor.

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Quantum Hall effect in polycrystalline CVD graphene: grain boundaries impact.

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The quantum Hall effect (QHE) observed in graphene is promising for an application to resistance metrology. Its robustness is an advantage to develop a quantum Hall resistance standard (QHR) surpassing the GaAs-based one's in operating at $B < 4$T and $T > 4$K and with higher measurement currents. This development relies on the fabrication of large graphene monolayer (of a few 10000 μm^2 size) characterized by an homogenous and low carrier density ($< 2.10^{11}$cm^{-2}) as well as a carrier mobility higher than 5000 cm^{2}V^{-1}s^{-1}. While it turned out that the exfoliation technique could not easily fulfil these requirements, it was demonstrated that epitaxial growth of graphene on silicon carbide allows the realization of a good QHR. Graphene growth based on chemical vapour deposition (CVD) seems another promising route to produce large high-quality graphene monolayers. We have studied the transport properties in the QHE regime of large (200 m wide) Hall samples made of polycrystalline graphene grown by pulsed CVD on copper and then transferred on a SiO2/Si substrate. These samples are characterized by carrier mobilities as high as 6000 cm^{2}V^{-1}s^{-1} and phase coherence lengths of 1-2 μm at 0.3 K. Well developed Hall resistance plateaus (including the $\nu = 0$ and $\nu = 1$ in certain samples) are observable at high magnetic field. However, it turns out that the longitudinal conductivity $\sigma_{xx}(T)$ as a function of temperature does not drop to zero as abruptly as expected around integer filling factors $\nu = \pm 2$ and $\nu = \pm 6$ notably. More precisely, our measurements show that $\sigma_{xx}(T)$ follows unexpected power laws which are not compatible with usual backscattering mechanisms like variable range hopping or inter-Landau level activation. It results that the Hall resistance is not quantized at the metrological level. Then, we will discuss the role of grain boundaries in causing enhanced backscattering through edge states short-circuiting.

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Origins of nonlocality near the neutrality point in graphene.

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Nonlocality in an electronic device means the appearance of an electric signal far away from the expected charge current path. It is common in several systems, for instance quantum Hall systems. Another context in which nonlocal signals are observed is when the charge current creates spin or heat currents that can flow in other directions than the charge excitation. In this talk I will discuss nonlocality near the neutrality point in graphene. The in-plane magnetic field dependence of the effect shows that spins play an important role [1], as predicted by the recent theory of the Zeeman Spin Hall Effect in graphene [2]. In addition, our work shows that thermo-magneto-electric effects give also rise to sizeable nonlocal signals.

[1] J. Renard et al arxiv:1309.7016.
[2] D.A. Abanin et al PRL 107 096601 (2011).

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Signatures of triplet supercurrents in hybrid S/F structures.

While ferromagnetism and conventional superconductivity appear as antagonist phases of nature, the proximity effect in hybrid S/F structures offers a unique opportunity to study their interplay. In particular, it has been shown that spin-triplet odd-frequency superconducting correlations may be induced in a diffusive ferromagnet. In a first part, we study the Josephson effect through a long ferromagnetic bilayer in the diffusive regime [1]. For non-collinear magnetizations between the two ferromagnetic layers, we find that the current phase relation is dominated by its second harmonic, and corresponds to the long-range coherent propagation of two triplet pairs of electrons. This can be viewed as the minimal Josephson current that can flow between the conventional singlet superconductor in one lead and the effectively triplet superconductor generated by the long-range proximity effect at the extremity of the ferromagnetic bilayer attached to the other lead. We then further explore the interplay between conventional superconductivity and effectively spin-triplet odd-frequency superconductivity in more complicated geometries. In particular, we study the temperature dependence of the critical current flowing between two effective triplet reservoirs through a conventional singlet superconductor. Under quite general conditions, the critical current presents a maximum in the vicinity of the superconducting transition of the central superconductor. This maximum is the signature of a competition between triplet/triplet and triplet/singlet Josephson couplings.

[1] C. Richard, M. Houzet, and J.S. Meyer, Superharmonic Long-Range Triplet Current in a Diffusive Josephson Junction, Phys. Rev. Lett. 110, 217004 (2013).

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Nonequilibrium fluctuation relations for adiabatically driven systems.

We investigate nonequilibrium relations between charge and energy currents and their fluctuations at the example of an interacting single-level quantum dot pump including external driving as well as a stationary external bias. For this purpose, we compute the full-counting statistics for both the charge and energy currents, and make use of the symmetries of the cumulant generating function due to microreversibility. We perform a consistent order-by-order expansion of the cumulant generating function in the driving frequency of the pump. While for zeroth order in the driving frequency we recover a time-averaged version of the Andrieux- Gaspard relations, we find that in the first order charge transport relations there appear corrections related to the total dissipated power. In particular, the time-averaged pumping current for zero bias is related to the linear bias response of the dissipated power. The zero bias pumping noise on the other hand is shown to be related to the linear bias response of the pumping current and a second order bias response of the dissipated power. Importantly, we show that this latter term vanishes for a noninteracting pump, resulting in an extension of the equilibrium fluctuation dissipation theorem to first order in the driving frequency. We furthermore investigate the second order relations where we show that there is a finite dissipation for zero bias due to nonadiabatic driving, which is directly related to the fluctuations of the dissipated power.

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Measuring the electric noise of a quantum switch.

We describe here the experiment we are currently performing in order to measure the electric noise generated by an electrical quantum switch. The quantum switch has attracted lots of theoretical interests due to its link with many-body entanglement entropy [1]. The switch considered here is a quantum point contact (QPC) which separates two electron reservoirs set at the same electrochemical potential. Let's consider only one channel in the QPC. When its transmission is equal to zero it corresponds to an open switch. The switch is closed by changing the gate voltage and having the channel transmission set to one. By driving quickly the gate voltage between these two states, we connect and disconnect the two electron reservoirs. After driving on and off the switch some electrons will be delocalized in both leads: the two Fermi seas are entangled. On a larger time scale the number of electrons in the reservoirs exhibit random fluctuations due to this entanglement. The associated current averages to zero because no bias is applied between the QPC but a finite current noise is generated by the switch. We performed the first noise measurements of a quantum switch using homemade cryogenic amplifiers in a dry dilution fridge. The noise of the quantum switch is expected to reach about 10^{-29} A^2/Hz. We compared experimental data to simulations of the current noise which take into account the actual electrical characteristic of the QPC. Up to now we have evidenced some spurious heating effects in the QPC that lead to some optimization of the RF set-up.

[1] Klich and Levitov, Phys. Rev. Lett. 102, 100502 (2009).

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Study of the hybrid entanglement between charge and oscillation modes and transport in a triple quantum dot shuttle : stationary and dynamical properties.

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Quantum entanglement is a central feature in quantum information and quantum computation. In this work we study the $3\times N$ hybrid entanglement between the charge and vibrational mode in a triple dot quantum shuttle (TDQS). Three quantum dots (QD's) are linearly connected, with the outer QD's fixed and the central QD oscillating, so that the tunneling between the QD's depends on the position of the central QD, which is described as a quantum harmonic oscillator with oscillation modes that are entangled with the electronic states of the QD's. The entangled states are characterized by the Schmidt number (K) as a function of the parameters of the TDQS: the detuning (ϵ_b) and the inverse of the tunneling length (α). We show that at steady state, the excited states of lower energy present entanglement $2\times N$, while the more energetic excited states, present a $3\times N$ entanglement as a function of ϵ_b, showing a maximum value of K for a fixed ϵ_b as a function of α. In the stationary regime we found relationships between the quantum phenomenon of entanglement and physical measurable properties: qualitative relationships between the maxima of the electronic current with the maxima of Schmidt number K The time evolution of the degree of entanglement for a particular initial condition is studied in the presence of an time-dependent electric field and we evaluate how the condition of coherent destruction of tunneling (CDT) affects the entanglement. Temporal averages of K were also obtained as a function of the TDQS parameters, finding specific regions in which the CDT condition decreases the degree of entanglement. The authors would like to thank DGAPA and project PAPIIT IN112012 for financial support.

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Transport quantique dans les nanofils InAs réalisés par épitaxie par jets moléculaires.

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Nonlinear time-dependent transport in Tunnel junctions: Universal Relations.

We have studied a spatially extended tunnel junction between two similar or different conductors with arbitrary dimensionality, internal or mutual interactions, disorder, coupling to an electromagnetic environment or quantum systems. An arbitrary time-dependent voltage, local magnetic field or/and the tunneling amplitudes are shown to affect non-trivially the average current at arbitrary frequencies, and that the latter can be expressed through the DC current only. The same fact holds for current correlations, provided one specifies to a thermal distribution; charge fluctuations are then shown to be universally poissonian if the junction is driven by a series of Lorentzian pulses. This work revisit generation of single excitations in non-linear conductors.

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Plasmon Mode Modifies the Elastic Response of a Nanoscale Charge Density Wave System.

We study electromechanical resonators of NbSe3 nanowires across the charge density wave (CDW) phase transition. The resonant frequency of mechanical vibrations is observed to have a sharp peak (~12.8% change in the elastic modulus) with the variation of temperature in the charge density wave phase. The nanoscale dimensions of the resonator lead to the excited phonon frequency being in close proximity of the plasmon mode of the electronic condensate; and the interaction between them is understood to be the reason for the occurrence of the peak in the temperature dependence of the elastic response.

Co-authors: Niveditha Samudrala, Vibhor Singh, Arumugam Thamizhavel, Peter B. Littlewood, Vikram Tri-

pathi, and Mandar M. Deshmukh (This work was done when I was at the Tata Institute of Fundamental Research, Mumbai). Ref: Physical Review Letters 110, 166403 (2013).

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Dynamical Coulomb Blockade in an interacting 1D system coupled to an environment.

In the last two decades, a lot of attention has been brought both theoretically and experimentally to the back action of an electromagnetic environment on the electronic transport properties of a coherent conductor. The majority of these studies was devoted to the case where the conductor reduces to a tunnel junction. The decrease of the conductance of the coherent conductor due to the environment is called the dynamical Coulomb blockade (DCB) and has been best studied within the well established so-called P(E) theory. In this talk, I will present the transport properties through a barrier coupled to an arbitrary electromagnetic environment and to interacting leads. I will first show that the weak and strong backscattering regimes are no longer connected by duality for dynamical properties such as the finite frequency noise. I will then apply our general formalism to the case where the environment describes a harmonic oscillator such as a LC circuit or a cavity.

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Persistent currents in Dirac-fermion rings.

We study persistent currents in two models of one-dimensional rings hosting Dirac fermions. First one is a model of helical fermions with a relativistic dispersion; a case which can be of relevance for the newly discovered two-dimensional topological insulators with metallic edge states exhibiting a relativistic dispersion. The second one is a lattice model that generates a single Dirac cone at the expense of breaking time-reversal symmetry. A comparison is drawn between the persistent currents in these two models and the usual case of non-relativistic fermions in small metallic rings. The main focus lies in studying the effect of a pointlike magnetic or non-magnetic impurity in these two systems. It is shown how a non-magnetic impurity does not affect the persistent current in the continuum model, while there is a suppression of the persistent current on the lattice. In contrast, a magnetic impurity has a similar effect in the two models. The results are generalized to non-zero temperature.

D. Sticlet, B. Dora, and J. Cayssol, arXiv:1307.6964 (accepted in Phys. Rev. B).

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Two-Component Fractional Quantum Hall Effect in the Half-Filled Lowest Landau Level in an Asymmetric Wide Quantum Well.

We investigate theoretically the recently observed fractional quantum Hall effect at half-filling in the lowest Landau level observed in asymmetric wide quantum wells that is when a potential bias is applied between the two sides of the well. Within exact-diagonalization calculations in the spherical geometry, we find that the incompressible state is described in terms of a two-component wave function the overlap of which can be optimized with the help of a rotation in the space of the pseudospin, which mimics the lowest two electronic subbands.

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Waiting time distributions for non-interacting fermions on a tight-binding chain.

The electronic waiting time distribution (WTD) is a new concept in mesoscopic physics to characterize the short-time behavior of single-electron transport processes. We calculate the WTD for several scatterers using a one-dimensional discrete lattice model. Our results are in excellent agreement with existing approaches and open a way for the calculation WTDs in one-dimensional systems with interactions.

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Electrically tunable charge transport in CVD-grown nanostructures of Bi2Se3.

Electrical transport in nanostructures of the 3D topological insulator Bi2Se3 is studied as a function of a back-gate voltage. Shubnikov de Haas oscillations indicate the presence of Dirac fermions, reproducing the results of previous studies based on exfoliated crystals [1], but here with a 4-probe geometry on CVD grown sampes. Besides, the simultaneous measure of both the longitudinal and transverse magneto-resistance allows us to compare the different carrier densities infered from Shubnikov-de-Haas oscillations and the Hall resistance. The strong back gate effect on the longitudinal and Hall resistances shows that we can efficiently tune the total carrier density in a nanostructure. Moreover, transport of the surface states is studied through Aharonov-Bohm effect, revealing a quasi-balistic regime for the Dirac fermions [2], in different crystal geometries.

[1] Sacépé et al., Nature Comm. 2, 575, (2011).
[2] J. Dufouleur et al., Phys. Rev. Lett. 110, 186806 (2013).

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Quasi-1D quantum dots in silicon nanowires: singlet state and valley splitting.

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Two weakly coupled 1D quantum dots are created at the two corners of a silicon nanowire by a large transverse electric field. Numerical simulations show that these quantum dots are very small in the transverse direction compared to their elongation along the channel. The mean level spacing (about 1 meV), the charging energy (about 20 meV) and the inter-dot capacitive coupling (1 meV) are determined by transport spectroscopy. Such high energies confirm the very small size of the dots. We are able to electrically detect the very first electrons in each dot. A magnetic dependence of the addition spectra proves that the two-electron ground state for each dot is a singlet up to 5.5T, corresponding to a double occupation of the lowest energy orbital. A specific feature of silicon quantum dots is valley degeneracy. The observation of a singlet state shows that this degeneracy has been lifted, by the confinement and electric field. This valley splitting is larger than those observed in usual 2DEG silicon heterostructures (0.1 meV) and smaller than those observed for single donors (10 meV) in silicon. These elongated 1D quantum dots represent a new playground for mesoscopic physics with the interplay of valleys, spins and orbital levels.

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Spin-orbit effects in nanowire-based wurtzite semiconductor quantum dots.

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Ref: Phys. Rev. B 88, 045303 (2013).

We study the effect of the Dresselhaus spin-orbit interaction on the electronic states and spin relaxation rates of cylindrical quantum dots defined on quantum wires having wurtzite lattice structure. The linear and cubic contributions of the bulk Dresselhaus spin-orbit coupling (SOC) are taken into account, along with the influence of a weak external magnetic field. The previously found analytic solution for the electronic states of cylindrical quantum dots with zinc blende lattice structures with Rashba interaction is extended to the case of quantum dots with wurtzite lattices. For the electronic states in InAs dots, we determine the spin texture and the effective g factor, which shows a scaling collapse when plotted as a function of an effective renormalized dot-size-dependent spin-orbit coupling strength. The acoustic-phonon-induced spin relaxation rate is calculated and the transverse piezoelectric potential is shown to be the dominant one.

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The best quantum thermoelectric at finite power output.

A thermoelectric device (heat-engine or refrigerator made using the Peltier effect) has Carnot efficiency if it is reversible, but then its power output is vanishingly small. So what is the maximal efficiency for an irreversible device with finite power output? We use a nonlinear scattering theory to answer this question for thermoelectric quantum systems (nanostructures or molecules). Maximum efficiency at given power output occurs when the system's transmission distribution is a top-hat function of energy, whose width is given by a transcendental equation. Quantum mechanics places an upper bound on power output. The efficiency is a function of the ratio of the power output to this bound, so it is explicitly quantum ($\hbar$-dependent). When the ratio is small, efficiency is below that of Carnot by an amount of order the square-root of the ratio. The suppression of efficiency by (nonlinear) phonon and photon effects is also calculated.

R.S. Whitney, arXiv:1306.0826

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Klein tunnelling transistor in ballistic graphene.

Today the availability of high mobility graphene up to room temperature makes ballistic nanostructures realizable. In particular, p-n-p transistor in the ballistic regime gives access to the Klein tunnelling physics and allows the realization of devices exploiting the optics-like behavior of Dirac Fermions (DF) as the well known Veselago lens or the Fabry Perot cavity. Here we propose a Klein tunnelling transistor based on geometrical optics of DF. We consider the case of a prism shaped gate where total internal reflection occurs, which leads to the suppression of the transistor transmission. We calculate the transmission and the current by means of scattering theory and the finite bias properties with non equilibrium Green function simulations (NEGF).

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