GDR 2426

Physique Quantique Mésoscopique

Aussois, 1 – 4 décembre 2014

ORGANISATEURS

Les responsables de la session
- **Richard Deblock**
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Lundi 1er décembre 2014

14:20 Opening

Session : Couplage conducteurs mésoscopiques et photons

14:30 *Crossover from quantized to continuous charge on a metallic node*
Anne Anthore (LPN et Université Paris Diderot)

15:00 *Single-electron double quantum dot dipole-coupled to a single photonic mode*
Julien Basset (LPS, Orsay)

15:30 *Generation of photon pairs at different frequencies. Route toward quantum microwave source*
Olivier Parlavecchio (SPEC, Saclay)

16:00 *Strongly correlated states in quantum dots from dissipative environments*
Serge Florens (Institut Néel, Grenoble)

16:30 Pause

17:00 *Universal non-equilibrium fluctuation dissipation relations*
Ines Safi (LPS, Orsay)

17:30 *Artificial spin/photon interface using a nanoscale spin valve*
Matthieu Dartiailh (LPA/ENS, Paris)

18:00 *Quantum dynamics of the driven and dissipative Rabi model*
Loic Henriet (Ecole Polytechnique)

18:30 *Long-range transfer of spin information using a single electron*
Benoit Bertrand (Institut Néel, Grenoble)

Session : Matière de Dirac et Vallée-tronique (partie 1)

19:00 *Optical k-valley state manipulation and excitonic effects in monolayer MoS2 and WSe2*
Xavier Marie (LPCNO, Toulouse)

19:45 Dîner

Mardi 2 décembre 2014

Session : Isolants et supraconducteurs topologiques

09:00 *Quantum coherent transport in valley-degenerate TCI films of SnTe grown by MBE*
Badih Assaf (ENS, Paris)

09:30 *Hybrid structures in helical liquids of topological insulators*
François Crépin (Universität Würzburg)

10:00 *Shapiro steps on a HgTe-based topological Josephson junction*
Erwann Bocquillon (Universität Würzburg)

10:30 Pause

11:00 *From Shiba to Majorana bound states in chains of magnetic atoms adsorbed on a superconductor*
Pascal Simon (LPS, Orsay)

11:30 *Kitaev edge modes in topological superconductors*
Mathias Diez (University of Leiden)

12:15 Déjeuner

Mardi 2 décembre 2014 (suite)

Session : Physique mésoscopique et atomes froids

15:45 *Ultracold atomic Fermi gases in two dimensions*
Michael Koehl (Universität Bonn)

16:30 *Violation of the Wiedemann-Franz Law for ultracold atomic gases*
Michele Filippone (Freie Universität Berlin)

17:00 *A mixture of Bose and Fermi superfluids*
Sébastien Laurent (LKB/ENS, Paris)

17:30 Pause

Session : Hybrides supraconducteurs

18:00 *Magnetic field resistant quantum interference in bismuth nanowire-based Josephson junctions*
Sophie Guéron (LPS, Orsay)

18:30 *Quasiclassical theory of disordered Rashba superconductors*
Julia Meyer (INAC/SPSMS, Grenoble)

19:00 *Spin Imbalance and Spin-Charge Separation in a Mesoscopic Superconductor*
Charis Quay (LPS, Orsay)

19:45 Dîner

21:00 Session Poster 1, Réunion bureau GDR

Mercredi 3 décembre 2014

Session : Matière de Dirac et Vallée-tronique

09:15 *From microwave resonators to artificial graphene*
Fabrice Mortessagne (LPMC, Nice)

09:45 *Valley polarisation assisted spin polarisation in two dimensions*
Vincent Renard (INAC/SPSMS, Grenoble)

10:15 Pause

10:45 *Electron-electron interactions in graphene as observed by magneto-Raman scattering*
Marek Potemski (LNCMI, Grenoble)

11:30 *Orbital magnetic susceptibility of multiband systems*
Frédéric Piechon (LPS, Orsay)

12:15 Déjeuner

16:15 *Shot noise generated by graphene p-n junctions in quantum Hall effect regime*
Norio Kumada (NTT Basic Research Laboratories)

16:45 *Quantum point contact in graphene in the quantum Hall regime*
Katrin Zimmermann (Institut Néel, Grenoble)

17:15 Pause

Session : systèmes 1D

17:45 *Traînée de Coulomb 1D-1D dans les fils quantiques verticalement couplés*
Guillaume Gervais (McGill University)

18:30 *Decay rates of quasiparticles in one-dimensional quantum liquids*
Zoran Ristivojevic (LPT, Toulouse)

19:00 Discussion GDR

19:45 Dîner

21:00 Session poster 2

Jeudi 4 décembre 2014

Session : Boîtes et points quantiques supraconducteurs

09:00 *Quantized charge pumping through superconductor - quantum dot - superconductor hybrids*
David van Zanten (Institut Néel, Grenoble)

09:30 *Evidence of phase dependent Kondo screening in a carbon nanotube Josephson junction*
Raphaëlle Delagrange (LPS, Orsay)

10:00 *Washing out of the 0-pi transition in Josephson junctions*
Rémi Avriller (LOMA, Bordeaux)

10:30 Pause

11:00 *Coherent manipulation of Andreev bound states*
Camille Janvier (SPEC, Saclay)

11:30 *Control of Andreev bound state population and related charge-imbalance effect*
Roman-Pascal Riwar (INAC/SPSMS, Grenoble)

12:15 Déjeuner

Session : Supraconductivité en dimensions réduites

14:30 *Proximity effect at the 2D limit and monolayer superconductivity: new insight from local probes*- Christophe Brun (INSP, Paris)

15:00 *Microwave electrodynamics and local tunneling spectroscopy of strongly disordered superconducting thin films*
Edouard Driessen (INAC/SPSMS, Grenoble)

15:30 *Top gating control of superconductivity at the LaAlO3/SrTiO3 interfaces*
Alexis Jouan (ESPCI, Paris)

16:00 Pause

Session : Systèmes nanomécaniques

16:30 *Resonant dynamics of a spin-nanomechanical hybrid system*
Olivier Arcizet (Institut Néel, Grenoble)

17:00 *Ultrashort single-wall carbon nanotubes reveal field-emission Coulomb Blockade and highest electron-source brightness*
Sorin Perisanu (Université de Lyon)

18:00 Départ navette

POSTERS TITLES

Pierre Adroguer	*Diffusion of Dirac fermions in presence of spin-orbit impurities*
J. Manuel Aguiar-Hualde	*Majorana Bound States in wires and ribbons*
Carles Altimiras	*Fluctuation-dissipation relations of a tunnel junction driven by a quantum circuit*
Paul Baireuther	*Andreev-Bragg reflection from an Amperian superconductor*
Franck Balestro	*Electrical detection and manipulation of a single nuclear spin*
Christopher Bauerle	*Theoretical, numerical, and experimental study of a flying qubit electronic interferometer*
Charlotte Bessis	*Influence of temperature on destructive quantum interferences in anthraquinone based junctions*
Roméo Bonnet	*Transport through functionalized multiwall carbon nanotubes contacted with ferromagnetic electrodes*
Adam Brandstetter-Kunc	*The dark side of plasmonic decay in a metallic nanoparticle dimer*
Landry Bretheau	*Quantum dynamics of an electromagnetic mode that cannot have N photons*
Laure Bruhat	*Dynamics of Kondo effect at finite frequency*
Boris Brun	*Possible Kondo phase shift in quantum point contacts probed by scanning gate microscopy*
Alexei Chepelianskii	*Probing Spin-Dependent Recombination at High Rabi Frequencies*
Denis Chevallier	*Spin accumulation in out of equilibrium mesoscopic superconductors*
Francesca Chiodi	*Superconducting silicon micro and nano devices*
Paul Clapera	*Silicon CMOS electron pumps: performances, integrated circuit and deep-UV version*
Andrea Corna	*A Silicon Artificial Atom*
Tristan Cren	*Josephson vortex cores: From direct imaging to an all-electronic control*
Bastien Dassonneville	*Topological insulator Josephson junctions: from geometrical to topological effects*
Pascal Degiovanni	*Real time decoherence of Landau and Levitov quasi-particles in quantum Hall edge channels*
Pierre Delplace	*Topological properties of periodically driven systems*
Matthieu Desjardins	*Microwave cavities as a probe of Kondo physics and Majorana fermions*
Olesia Dmytruk	*Charge susceptibility in a resonant quantum RC circuit*
Clément Dutreix	*Spin-Singlet Superconductivity and Majorana Modes in the Honeycomb Lattice*
Jean-Eudes Duvauchelle	*Subgap conductances in three terminal SNS Josephson junctions under microwave irradiation*
Lars Elster	*Manipulation of Andreev bound states in unconventional Josephson junctions*
Pierre Février	*Measurement of the electronic quantum shot noise at optical frequencies*
Denis Feinberg	*Transport in triterminal hybrid structures*

Michel Fruchart	*Topology of driven crystals*
Jean-Noël Fuchs	*Stückelberg interferometry with a pair of Dirac cones in artificial graphene*
Cosimo Gorini	*Room temperature spin thermoelectrics in metallic films*
Alexander Grimm	*Correlations of microwave photons emitted by inelastic Cooper pair tunneling*
Andrii Gudyma	*Breathing modes of one-dimensional trapped BEC*
Sophie Guéron	*Superconducting proximity effect through graphene grafted with Pt-porphyrins: detection of gate-tunable magnetism.*
Marine Guigou	*Density of states of interacting quantum wires with impurities: a Dyson equation approach*
Sébastien Guissart	*Kondo effect of an atom in contact with a multilayered tip*
Hugo Henck	*Electronic transport with Epitaxial Graphene and 2D-heterostructures*
Loïc Huder	*Effect of a molecular grafting on electronic transport in epitaxial graphene*
Jimmy Hutasoit	*Magnon electrodynamics in Weyl semimetals*
Andreas Inhofer	*High frequency response of 3d topological insulators*
Romain Jacquet	*Cooper pair splitting in a nano-SQUID geometry at high transparency*
Salha Jebari	*Parametric amplifier based on a voltage biased Josephson junction*
Li-Jing Jin	*How to detect the inelastic scattering of photons propagating in a non-linear electromagnetic resonator*
Vardan Kaladzhyan	*Photo-emf in a conductor tunnel coupled to 2D topological insulator*
Tatiana Krishtop	*Nonlocal transport and heating in superconductor hybrid structures in the presence of a Zeeman field*
Thibaud Louvet	*Minimal conductivity in semi-metallic phases*
Arthur Marguerite	*Hong-Ou-Mandel experiment for temporal investigation of single electron fractionalization*
Romain Maurand	*Single hole physics in Si and Si/Ge Nanowire Transistors: Towards Quantum Spintronics*
Gerbold Ménard	*Spatial structure at atomic scale of individual magnetic impurities in NbSe2 resolved by STS*
Tristan Meunier	*Using a two-electron spin qubit to detect flying electrons*
Gianluca Micchi	*Dynamical behavior of suspended carbon nanotubes close to the current blockade transition*
Sergey Mironov	*Josephson coupling through a single nanowire: multi-periodic SQUID-like oscillations of the critical current*
Fabien Navarin	*Phase shift of quantum oscillations as function of sample boundary conditions*
Konstantin Nesterov	*Anomalous Josephson Effect in Junctions with Rashba Spin-Orbit Coupling*
Ciprian Padurariu	*Quasi-classical circuit theory of mesoscopic junctions with three superconducting terminals*
Fabio Pistolesi	*Single Molecules coupled to nano-oscillators: strong coupling limit*
Rosario Elio Profumo	*Systematic electron-electron interaction corrections to nanoelectronics device properties*
Arnaud Raoux	*Orbital Magnetism of Multiband Systems*

Caroline Richard	*Heat current through inhomogeneous superconductors (e.g. presence of a domain wall)*
Laurent Saminadayar	*Stress induced excitations in a spin glass*
Marc Sanquer	*Silicon artificial atoms with large charging energies based on a scalable deep-UV lithography process*
Nicholas Sedlmayr	*Flat bands of Majoranas in 2d - topology and stability*
Shintaro Takada	*Transmission Phase Shift across a Quantum Dot with Strong and Weak Kondo Correlations*
Brian Tarasinski	*Scattering theory of topological phases in discrete-time quantum walks*
Etienne Thibierge	*Two-particle electronic coherence in quantum Hall channels*
Mircea Trif	*Non-classical light emitted by a voltage-biased Josephson junction coupled to two resonators*
Louis Veyrat	*Aharonov-Bohm oscillations in quantum wire of 3D-topological insulator*
Guillaume Weick	*Large current noise in nanoelectro mechanical systems close to continuous mechanical instabilities*
Dietmar Weinmann	*Transmission phase of a quantum dot and statistical fluctuations of partial-width amplitudes*
Marc Westig	*Josephson junction embedded in a resonator: from Coulomb blockade to parametric resonance*
Joseph Weston	*Manipulating Andreev and Majorana Bound States with radio-frequency*
Robert Whitney	*Most efficient quantum thermoelectric at finite power output*
Quentin Wilmart	*A gate-tunable contact junction in graphene*
Clemens Winkelmann	*Transport vs local properties of mesoscopic graphene devices*

TALK ABSTRACTS

Lundi 1er décembre 2014

Session : Couplage conducteurs mésoscopiques et photons

A. Anthore , LPN, Marcoussis
S. Jezouin, Z. Iftikhar, F.D. Parmentier, A. Anthore, U. Gennser, A. Cavanna, F. Pierre

Crossover from quantized to continuous charge on a metallic node

On a simple piece of metal, charge is quantized. Yet, in most of the electronic circuits, despite the granularity of charge transfer, no hints of charge quantization remain. To observe and exploit charge quantization effects, people have realized metallic nodes weakly connected to the circuit through tunnel contacts, as, for example, in a single electron transistor. Beyond tunnel junctions, quantized charging effects can arise in circuits made of coherent conductors and strongly modify the electrical transport. So, what governs the crossover from quantized to continuous charge on a metallic node? In this talk, I will present our experimental investigation of charge quantization in a node, when the coupling of the node to the circuit evolves from tunnel regime to ballistic regime. A single electron transistor was realized where the two tunnel junctions were replaced by quantum conductors with electronic quantum channels of arbitrary transmission probabilities. When approaching the ballistic regime, this circuit is also called an open quantum dot. The charge quantization is revealed by a periodic modulation of the circuit zero-bias conductance when sweeping the voltage applied to a gate capacitively coupled to the island, and is characterized by the visibility of conductance variations. Theory predicts that charge quantization in the island is reduced by quantum fluctuations as the transmission probabilities (τ) increase, and that it is completely destroyed as soon as one conduction channel is ballistic [1]. In our experiment, we can precisely check this prediction by measuring independently the transmission probabilities of the two coherent conductors, and avoiding spurious direct coherence effect between them. It closes a long standing debate as regard charging effects in open quantum dots [2,3,4]. Furthermore, we focus on the quantum crossover near full transmission, and find that the visibility signaling charge quantization vanishes as the squareroot of ($1-\tau$), in agreement with the two-decade old prediction. Finally, our data provide a blueprint for charge quantization versus transmission probabilities at different temperatures in regime not yet covered by theory.

[1] A.Furusaki K.A.Matveev, Theory of strong inelastic cotunneling PRB 52, 16678 (1995).
[2] L.P. Kouwenhoven, N.C. van der Vaart, A.T. Johnson, W. Kool, C.J.P.M. Harmans, J.G. Williamson, A.A.M. Staring, and C.T. Foxon, Z. Phys. B. Condensed Matter 85, 367 (1991).
[3] C. Pasquier, D.C. Glattli, U. Meirav, F.I.B. Williams, Y. Jin, B. Etienne, Surface Science 263, 419 (1992).
[4] C.-T. Liang, M. Y. Simmons, C. G. Smith, G. H. Kim, D. A. Ritchie, and M. Pepper, PRL 81, 3507 (1998).

Julien Basset, LPS, Orsay
J. Basset, A. Stockklauser, V. Maisi, D.-D. Jarausch, T. Frey, C. Reichl, W. Wegscheider, T. M. Ihn, K. Ensslin, and A. Wallraff

Single-electron double quantum dot dipole-coupled to a single photonic mode

We have realized a hybrid solid-state quantum device [1] in which a single-electron semiconductor double quantum dot is dipole-coupled to a superconducting microwave frequency transmission line resonator. The dipolar interaction between the two entities manifests itself via dispersive and dissipative effects observed as frequency shifts and linewidth broadenings of the photonic mode respectively. A Jaynes-Cummings Hamiltonian master equation calculation is used to model the combined system response. It allows for determining both the coherence properties of the double quantum dot and its interdot tunnel coupling with high accuracy [2]. Decoherence properties of the double dot are investigated as a function of the number of electrons inside the dots. They are found to be similar in the single-electron and many-electron regimes suggesting that the density of the levels in the discrete energy spectrum plays a minor role in the decoherence rate of the system under investigation [2]. While driven out-of-equilibrium with a source-drain voltage bias, the double quantum dot system emits photons into the resonator. We analyze the flow of these emitted photons leaking out of the resonator into our detection chain and tentatively relate it to the electron statistics provided by the double dot.

1- M. R. Delbecq et al., Phys. Rev. Lett. 107, 256804 (2011); T. Frey et al., Phys. Rev. Lett. 108, 046807 (2012); K. D. Petersson et al. Nature (London) 490, 380 (2012).
2- J. Basset et al. Phys. Rev. B 88, 125312 (2013).

Olivier Parlavecchio, SPEC, Saclay
O. Parlavecchio, C. Altimiras, M. Hofheinz, P. Joyez, D. Vion, P. Roche, D. Esteve, and F. Portier

Generation of photon pairs at different frequencies. Route toward quantum microwave source.

The dynamical Coulomb blockade (DCB) of tunnelling is a quantum phenomenon in which tunneling of charge through a small tunnel junction is modified by its electromagnetic environment. The sudden charge transfer associated with tunnelling generates photons in the electromagnetic modes of the environment. In a normal metal tunnel junction, biased at voltage V, the energy eV of a tunnelling electron can be dissipated both into quasiparticle excitations in the electrodes and into photons. At low temperature energy conservation forbids tunnelling processes emitting photons with total energy higher than eV, which reduces the conductance at low bias voltage. In a Josephson junction, DCB effects are more prominent since at bias voltages smaller than the gap voltage $2\Delta/e$ quasiparticle excitations cannot take away energy and the entire energy of tunnelling Cooper pairs has to be transformed into photons in the impedance for a dc current to flow through the junction. We have recently observed and characterized the radiation associated to the flow of Cooper pairs connected to a microwave resonator. Our new experiment can be schematically represented as follows: a Josephson junction is placed between two microwave resonators with different resonant frequencies, ν_1 and ν_2, and is voltage biased at voltage V, such that $2eV = h\nu_1+h\nu_2$. The tunnelling of a Cooper pair is then associated to the emission of one photon into each of the resonators. Our setup routes the photons leaking out of each resonators into separate microwave amplifiers, allowing to detect and analyse the emitted radiation at room temperature. It has recently been shown by Leppégankas and co-workers that the radiation emitted by these two photon-processes is non classical, and that it violates a classical

Cauchy-Schwarz inequality for two-mode power cross-correlated fluctuations. The basic idea is that the probability of emitting a photon in each of the resonators during the observation time is higher that the geometric mean of the probability of emitting two photons in either one of them. I will present our experimental results where the classical inequality is violated.

Serge Florens, Institut Néel, Grenoble

Strongly correlated states in quantum dots from dissipative environments

This talk will address, both theoretically and experimentally, the generation and detection of many-body states using high impedance circuits in contact to quantum dots. It will start with recent conductance measurements on carbon nanotube devices in a "tunneling noise" geometry, showing the existence of a non-trivial quantum critical state [1,2]. Various scaling laws will be thoroughly examined with remarkable consistency. A second and different setup (à la Caldeira-Leggett) will then be considered, using "charge noise" processes [3,4]. Here, non-linear microwave AC transport in Josephson junction arrays will be tackled, using a coherent state wavepacket quantum dynamics [5,6]. The question of measuring photonic analogs of the Kondo screening cloud will finally be discussed [7].

[1] "Observation of Majorana Quantum Critical Behavior in a Resonant Level Coupled to a Dissipative Environment", H. T. Mebrahtu, I. V. Borzenets, H. Zheng, Y. V. Bomze, A. I. Smirnov, S. Florens, H. U. Baranger, and G. Finkelstein, Nature Physics 9, 732 (2013).
[2] "Transport Signatures of Majorana Quantum Criticality Realized by Dissipative Resonant Tunneling", H. Zheng, S. Florens, and H. U. Baranger, Phys. Rev. B 89, 235135 (2014).
[3] "Kondo Resonance of a Microwave Photon", K. Le Hur, Phys. Rev. B 85, 140506(R) (2012).
[4] "Inelastic Microwave Photon Scattering off a Quantum Impurity in a Josephson-Junction Array", M. Goldstein, M. H. Devoret, M. Houzet, and L. I. Glazman, Phys. Rev. Lett. 110, 017002 (2013).
[5] "Non-linear photon scattering onto the Kondo state", S. Bera, H. U. Baranger, and S. Florens, (in preparation).
[6] "A generalized multi-polaron expansion for the spin-boson model: Environmental entanglement and the biased two-state system", S. Bera, A. Nazir, A. W. Chin, H. U. Baranger, and S. Florens, Phys. Rev. B 90, 075110 (2014).
[7] "Microscopics of the Kondo screening cloud", I. Snyman and S. Florens, (in preparation).

Ines Safi, LPS, Orsay

Universal non-equilibrium fluctuation dissipation relations

We develop a very general perturbative computation of finite-frequency noise, which applies, in particular, to both a good or weakly transmitting strongly correlated conductor, independently on experimental details and many-body correlated states. In addition, the conductor can be coupled to an electromagnetic environment or other quantum conductors. We show that finite frequency (FF) noise can be expressed in a universal way through the non-equilibrium DC current only, yielding perturbative time-dependent non-equilibrium fluctuation dissipation relations (FDRs). This unifies our previous works using specific models (2,3). We then present a synthetic overview of the frequency and DC bias dependence of the FF noise, independently from any specific model. In particular, we show that in the quantum regime, there is still thermal noise at frequencies close to the DC bias. Using the exact non-equilibrium FDR relating the asymmetric part of the FF noise to the non-equilibrium admittance (1,2), we show that the latter can be as well expressed through the DC current. We then discuss the FDRs obtained in presence of time dependent voltages (4,5) Which have motivated recent work recently performed at SPEC (6)

(1) Ines Safi and Philippe Joyez, Phys. Rev. B 84, 205129 (2011)
(2) I. Safi, C. Bena, and A. Crépieux, Phys. Rev. B 78, 205422 (2008)
(3) C. Bena and I. Safi, Phys. Rev. B 76, 125317 (2007) ; J. R. Souquet, I. Safi and P. Simon, Phys. Rev. B (2013).
(4) I. Safi and E. V. Sukhorukov, EPL (Europhysics Letters) 91, 67008 (2010).
(5) I. Safi, arXiv:1401.5950
(6) Olivier Parlavecchio et al arXiv:1409.6696

Matthieu Dartiailh, LPA, ENS, Paris
J. J. Viennot, M. C. Dartiailh, A. Cottet, and T. Kontos

Artificial spin/photon interface using a nanoscale spin valve

The main goal in the recent development of hybrid circuit quantum electrodynamics with quantum dots is to find efficient means to couple single spins to cavity photons. So far though, only the coupling of photons to the charge degree of freedom could be demonstrated. Here, we demonstrate a large spin photon coupling in a cQED architecture. Our scheme relies on the use of a non collinear spin valve which realizes an artificial spin orbit interaction. Thanks to that interaction we are able to couple states which are sensitive to the external magnetic field. We observe a hysteretic evolution of the phase of the microwave signal as a function of the external magnetic field stemming from the spin valve behavior of the device. This demonstrates an efficient spin/photon coupling and illustrates a new method for manipulating the quantum mechanical spin degree of freedom. Our findings could be used to scale up spin quantum bit architectures.

Loic Henriet, CPHT, Ecole Polytechnique, Palaiseau

Quantum dynamics of the driven and dissipative Rabi model

The Rabi model describes the simplest interaction between matter and light. The recent experimental progress in solid-state circuit quantum electrodynamics has engendered theoretical efforts to quantitatively describe the mathematical and physical aspects of the light-matter interaction beyond the rotating wave approximation. We develop a stochastic Schrédinger equation approach which enables us to access the strong-coupling limit of the Rabi model and study the effects of dissipation and AC drive in an exact manner. We include the effect of ohmic noise on the non-Markovian spin dynamics as well as cavity losses. We compute the time evolution of spin variables in various conditions. As a scope, we discuss the possibility to reach a steady state with one polariton in realistic experimental conditions.

Phys. Rev. A 90, 023820 (2014): L. Henriet, Z. Ristivojevic, P.P. Orth, K. Le Hur

Benoit Bertrand, Institut Néel, Grenoble
B. Bertrand, A. D. Wieck, C. Bäuerle and T. Meunier

Long-range transfer of spin information using a single electron

Electron spin is a very promising candidate for quantum computing because the spin degree of freedom is highly decoupled from the charge environment in a nanostructure. In this respect, GaAs lateral quantum dots have proven to be good candidates for spin qubit implementation: qubit initialisation, rotation and two-qubit operations have been demonstrated successfully. The recently demonstrated on-demand transfer of a single electron using surface acoustic waves in AlGaAs heterostructures [1,2] opens the route towards electronics at the single electron level and is a promising strategy to scale up the system of electron spin qubits. We will discuss the result of an experiment where an electron spin, initially prepared in a specific spin state in a first dot, is measured after transfer to a second dot three microns away. We will demonstrate that spin information is partially preserved during the transfer and we will discuss possible source of depolarization during the transfer and prior to the transfer.

[1] S. Hermelin, S. Takada, M. Yamamoto, S. Tarucha, A. D. Wieck, L. Saminadayar, C.Bauerle and T. Meunier, Nature (London) 447, 435 (2011)
[2] R. P. G. McNeil, M. Kataoka, C. J. B. Ford, C. H. W. Barnes, D. Anderson, G. A. C. Jones, I. Farrer & D. A. Ritchie Nature (London) 447, 439 (2011)

Session : Matière de Dirac et Vallée tronique (partie 1)

Xavier Marie, LPCNO, Toulouse
G. Wang, L. Bouet, D. Lagarde, M. Vidal, I. Gerber, T. Amand, X. Marie, B. Urbaszek

Optical k-valley state manipulation and excitonic effects in monolayer MoS2 and WSe2

In strong analogy to graphene, the physical properties of transition metal dichalcogenides (TMDCs) change drastically when thinning the bulk material down to one monolayer (ML) [1]. The closely related ML materials WSe2, MoS2, MoSe2 and WS2 are 2D semiconductors with strong, direct optical transitions that are governed by tightly Coulomb bound electron-hole pairs (excitons). Their optoelectronic properties are directly related to the inherent crystal inversion symmetry breaking. It allows for efficient second harmonic generation (SHG), shown in the figure, and is at the origin of chiral optical selections rules, which enable efficient optical initialization of electrons in specific K-valleys in momentum space in the emerging field of valleytronics [1]. Here we investigate the stability of the initialized valley states in ML MoS2 and WSe2 in time resolved photoluminescence (PL) experiments [2]. We extract the PL emission time and the valley depolarization time for excitons (electron-hole pairs) and trions (2 electrons & 1 hole). For excitons, the valley polarization decays within ps due to Coulomb exchange. After an initial decay the trion valley polarization reaches a stable plateau with a decay time of about 1ns. By performing SHG spectroscopy in ML WSe2 as a function of laser energy and polarization, we record an enhancement by up to 3 orders of magnitude of the SHG efficiency when in resonance with exciton states due to the interplay between the electric dipole and, very unusually, magnetic dipole transitions. We probe the symmetry of the excited exciton states in 1 and 2-photon absorption. We demonstrate coherent alignment of excitons following two-photon excitation and confirm excited exciton states in first principle calculations including strong anti-screening effects.

This work is financed by ERC Grant No. 306719. We thank our collaborators B.L. Lui and P.H. Tan (CAS, Beijing, China) and M.M. Glazov (Ioffe Institute, Russia).

[1] X. Xu, W. Yao, Di Xiao, T. Heinz , Nature Physics nphys2942 (2014) [2] D. Lagarde et al PRL 112, 047401 (2014) & G. Wang et al PRB 90, 075413 (2014) [3] G. Wang, et al., arXiv: 1404.0056

Mardi 2 décembre 2014

Session : Isolants et supraconducteurs topologiques

Badih Assaf, ENS, Paris

Quantum coherent transport in valley-degenerate TCI films of SnTe grown by MBE

Time-reversal symmetric topological insulators (TI) - such as Bi2Se3 and Bi2Te3 - are the most common among topological materials. In such systems, a single band inversion that occurs at the time-reversal symmetric ?-point of the Brillouin zone leads to a single topologically-protected Dirac surface-state. In contrast, topological crystalline insulators (TCI) are a novel subclass of topological matter where an even number of band inversions that occur at mirror symmetric points in the Brillouin zone leads to an even number of topologically-protected surface-states [1]. The valley-degenerate surface of a TCI brings forth a number of exciting prospects and challenges to the field of topological matter. This talk will focus, in particular, on results from coherent magnetotransport measurements performed on SnTe TCI thin film grown by MBE on BaF2 (001) substrates. The growth parameters are tuned to modulate the carrier density and mobility of SnTe. Weak antilocalization (WAL) is observed and studied. The magnitude of the WAL is seen to have a non-trivial variation as a function of the Fermi level and the phase coherence length. This variation is a likely result of coherent intervalley scattering that couples the WAL channels originating from different surface Dirac valleys. This is, partly, a consequence of the surface band degeneracy that is peculiar to TCI [2].

[1]T.H. Hsieh, H. Lin, J. Liu, W. Duan, A. Bansil, and L. Fu. Nature Commun. 3, 982 (2012).
[2] B.A. Assaf, F. Katmis, P. Wei, B. Satpati, Z. Zhang, S.P. Bennett, V.G. Harris, J.S. Moodera, D. Heiman. Appl. Phys. Lett. 105, 102108, (2014).

François Crépin, Würzburg Universität
F. Crépin and B. Trauzettel

Hybrid structures in helical liquids of topological insulators

Helical liquids (one dimensional electron gases with spin-momentum locking) whether emerging in spin-orbit nanowires or at the edges of 2D topological insulators provide a remarkable platform for the study of unconventional superconductivity. The interplay between helicity and proximity-induced electron pairing leads to quite rich physics, ranging from fractionnal Josephson effects to the emergence of exotic quasi-particles. We first study N-S and S-N-S junctions at the helical edge of a 2D topological insulator, and discuss their behavior in the presence of an arbitrary ferromagnetic scatterer, focusing on their spectral properties as well as on the localization of Andreev and Majorana bound states wave functions [1]. Using a Green's functions approach, we also analyse in details the symmetries of the pairing amplitude in these inhomogeneous junctions and try to relate instances of p-wave superconductivity to observable quantities [3]. In a second part, we turn to the specific case of a topological Josephson junction made of both edges of a 2D topological insulator. Due to fermion parity pumping across the bulk, we find that the global parity of the number of quasi-particles in the junction has a clear signature in the periodicity and critical value of the supercurrent [2], a result that is, in the case of long junctions, robust to the inclusion of Coulomb interactions.

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[2] F. Crépin, B. Trauzettel, Phys. Rev. Lett. 112, 077002 (2014)
[3] F. Crépin, B. Trauzettel (unpublished).

Erwann Bocquillon, Würzburg Universität

Shapiro steps in a HgTe-based topological Josephson junction

In the surface states of a three-dimensional topological insulator, transport is mediated by Dirac-like fermions which exhibit helical spin polarization. The latter remarkable property is predicted to give rise to unconventional p-type superconductivity in a topological insulator-superconductor Josephson junction, thus arousing a considerable theoretical and experimental interest. In particular, zero-energy Andreev bound states with topological protection are expected to appear, opening the way to robust manipulation of quantum states. However, the experimental observation of such gapless states is difficult in transport experiments due to the parallel contribution of conventional states, and, so far, experimental evidence of such gapless states are very scarce. Here, using strained bulk HgTe as a 3D TI, we report on the observations of anomalies in the AC Josephson effect of a S-TI-S junction. Namely, at low excitation frequency and low power, we observe a disappearance of the first (odd) Shapiro step. We discuss the possibility to attribute this signature to the topological bound states, as proposed theoretically [1,2].

[1] F. Dominguez et al., PRB 86, 140503, (2012)
[2] M. Houzet et al., PRL 111, 046401, (2013)

P. Simon, LPS, Orsay

From Shiba to Majorana bound states in chains of magnetic atoms adsorbed on a superconductor

A classical magnetic impurity in a superconductor gives rise to a so-called Shiba bound state (SBS). Scanning tunneling Microscopy offer a natural tool to study the spatial extent of the SBS wave function. Contrary to previous studies, we show that the wave function extends far tens of nano-meters away from the impurity suggesting that interactions between distant magnetic spins in superconductors could be long-ranged. When many magnetic atoms are arranged to form a 1D chain on top of the superconductor, they form a Shiba band. We show that the ground state of magnetic spins adsorbed on a superconductor is actually a magnetic helical order and therefore may offer a natural platform for topological superconductivity and hence Majorana bound states [1].

[1] B. Braunecker and P. Simon, Phys. Rev. Lett. 111, 147202 (2013).

Mathias Diez, Instituut-Lorentz, Universiteit Leiden
M. Diez, I. C. Fulga, D. I. Pikulin, J. Tworzydło, C. W. J. Beenakker

Kitaev edge modes in topological superconductors

A two-dimensional superconductor with spin-triplet p-wave pairing supports chiral or helical Majorana edge modes with a quantized (length L-independent) thermal conductance. Sufficiently strong anisotropy removes both chirality and helicity, doubling the conductance in the clean system and imposing a super-Ohmic 1/L decay in the presence of disorder. We explain the absence of localization in the framework of the Kitaev Hamiltonian, contrasting the edge modes of the two-dimensional system with the one-dimensional Kitaev chain. While the disordered Kitaev chain has a log-normal conductance distribution peaked at an exponentially small value, the Kitaev edge has a bimodal distribution with a second peak near the conductance quantum. Shot noise provides an alternative, purely electrical method of detection of these charge-neutral edge modes.

New J. Phys. 16, 063049 (June, 2014).

Session : Physique mésoscopique et atomes froids

Michael Koehl, University of Bonn

Ultracold atomic Fermi gases in two dimensions

Pairing of fermions is ubiquitous in nature. It is responsible for a large variety of fascinating phenomena like superconductivity, superfluidity of 3He, and the anomalous rotation of neutron stars. Ultracold atomic Fermi gases allow for a particularly clean experimental realization of these quantum many-body systems and for addressing long-standing open questions. In this talk, we focus on situations in which the motion of particles is confined to two-dimensional layers. Such low-dimensional, interacting many-body systems bear subtle effects, which are not encountered in three dimensions. We will review our recent experiments regarding quasiparticle spectroscopy, spin diffusion measurements and in-situ observation of Mott-insulating domains.

Michele Filippone, Freie Universität Berlin
Michele Filippone, Frank Hekking, Anna Minguzzi

Violation of the Wiedemann-Franz Law for ultracold atomic gases

We study energy and particle transport for one-dimensional strongly interacting bosons through a single channel connecting two atomic reservoirs. We show the emergence of particle- and energy-current separation, leading to the violation of the Wiedemann-Franz law. As a consequence, we predict different time scales for the equilibration of temperature and particle imbalances between the reservoirs. Going beyond the linear spectrum approximation, we show the emergence of thermoelectric effects, which could be controlled by either tuning interactions or the temperature. Our results describe in a unified picture fermions in condensed matter devices and bosons in ultracold atom setups. We conclude discussing the effects of a controllable disorder.

Sébastien Laurent, LKB, ENS, Paris
I. Ferrier-Barbut, M. Delehaye, S. Laurent, A. T. Grier, M. Pierce, B. S. Rem, F. Chevy, C. Salomon

A mixture of Bose and Fermi superfluids

Superconductivity and superfluidity of fermionic and bosonic systems are remarkable many-body quantum phenomena. In liquid helium and dilute gases, Bose and Fermi superfluidity has been observed separately, but producing a mixture in which both the fermionic and the bosonic components are superfluid is challenging. We report on the observation of such a mixture with dilute gases of two lithium isotopes, lithium-6 and lithium-7 [1]. We probe the collective dynamics of this system by exciting center-of-mass oscillations. Using high-precision spectroscopy of these modes, we observe coherent energy exchange and measure the coupling between the two superfluids. And by varying the relative velocity between the two clouds, we identify a critical velocity below which only extremely low damping is observed. This critical velocity can be understand in terms of a generalized Landau cirtical velocity for finite mass impurity in a Fermi superfluid [2].

[1] I. Ferrier-Barbut et al. Science 345, 1035 (2014);
[2] Y. Castin et al. arXiv 1408.1326

Session : Hybrides supraconducteurs

Sophie Guéron, LPS, Orsay
Chuan Li, A. Kasumov, A. Murani, Shamashis Sengupta, F. Fortuna, K. Napolskii, D. Koshkodaev, G. Tsirlina, Y. Kasumov, I. Khodos, R. Deblock, M. Ferrier**,** S. Guéron and H. Bouchiat

Magnetic field resistant quantum interference in bismuth nanowires-based Josephson junctions

We investigate proximity induced superconductivity in micrometer-long bismuth nanowires connected to superconducting electrodes with a high critical field. At low temperature we measure a supercurrent that persists in magnetic fields as high as the critical field of the electrodes (above 10 T). The critical current is also strongly modulated by the magnetic field. In certain samples we find regular, rapid SQUID-like periodic oscillations occurring up to high fields. Other samples exhibit less periodic but full modulations of the critical current on Tesla scales, with field-caused extinctions of the supercurrent. These findings indicate the existence of low dimensionally, phase coherent, interfering conducting regions through the samples, with a subtle interplay between orbital and spin contributions. We relate these surprising results to the electronic properties of the surface states of bismuth, strong Rashba spin-orbit coupling, large effective g factors, and their effect on the induced pair correlations.

arXiv:1406.4280

Julia Meyer, INAC/SPSMS, Grenoble
Julia S. Meyer & Manuel Houzet

Quasiclassical theory of disordered Rashba superconductors

The interplay of Zeeman fields and spin-orbit coupling has been predicted to yield interesting effects in bulk superconductors as well as in Josephson junctions. Namely their combined effect favors a spatial variation of the superconducting phase, which in the bulk should lead to an anisotropy of the critical current [1] whereas in Josephson junctions it may induce a Josephson current at zero phase difference [2].

So far microscopic calculations exist only in the clean case. To study these effects in disordered systems, we derive the quasiclassical equations that describe two-dimensional superconductors with a large Rashba spin-orbit coupling and in the presence of impurities. These equations account for the so-called helical phase, where the superconducting order parameter is spatially modulated along the direction perpendicular to an applied Zeeman field. We apply this formalism to compute the upper critical field in the diffusive regime. Our theory also paves the way for studies on the proximity effect in

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2. A. I. Buzdin, Phys. Rev. Lett. **101**, 107005 (2008).

Charis Quay, LPS, Orsay
Charis Quay Huei Li, D. Chevallier, C. Dutreix, M. Guigou, C. Bena, M. Aprili

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 (respectively Q* and S*). 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 and experimentally, spin imbalances have not received much experimental attention despite intriguing theoretical predictions of spin-charge separation effects. 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. We present evidence for an almost-chargeless spin imbalance in a mesoscopic superconductor. These experiments allow us to explore transport scenarios in which spin and charge degrees of freedom are separately addressed. These experiments yield an estimate of the spin imbalance lifetime based on fits to theory. We have recently been able to determine this quantity independently and more directly, using frequency domain measurements.

[1] Spin imbalance and spin-charge separation in a mesoscopic superconductor, C. H. L. Quay, D. Chevallier, C. Bena and M. Aprili, Nature Physics, 9, 84-88 (2013).
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mercredi 3 décembre 2014

Session : Matière de Dirac et Vallée Tronique

Fabrice Mortessagne, LPMC, Nice
Matthieu Bellec, Gilles Montambaux, Ulrich Kuhl and Fabrice Mortessagne

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-zak or bearded, the anisotropy leads to specific edge states that I will also present.

PRL 110, 033902 (2013) ; PRB 88, 115437 (2013) ; HAL-01011880 (NJP, in press)

Vincent Renard, INAC/SPSMS, Grenoble
V. T. Renard, B. A. Piot, X. Waintal, G. Fleury, Y. Niida, D. Tregurtha, A. Fujiwara, Y. Hirayama and K. Takashina

Valley polarisation assisted spin polarisation in two dimensions

Valleytronics is rapidly emerging as an exciting area of basic and applied research. In two dimensional systems, valley polarisation can dramatically modify physical properties through electron-electron interactions as demonstrated by such phenomena as the Fractional Quantum Hall Effect and the Metal-Insulator Transition. Here, we address the electrons' spin alignment in a magnetic field in silicon-on-insulator quantum wells under valley polarisation. In stark contrast to expectations from a non-interacting model, we show experimentally that less magnetic field can be required to fully spin polarise a valley-polarised system than a valley-degenerate one. Furthermore, we show that these observations are quantitatively described by parameter free ab initio Quantum Monte Carlo simulations. We interpret the results as a manifestation of the greater stability of the spin and valley degenerate system against ferromagnetic instability and Wigner crystalisation which in turn suggests the existence of a new strongly correlated electron liquid at low electron densities.

Marek Potemski, LNCMI, Grenoble

Electron-electron interactions in graphene as observed by magneto-Raman scattering

Investigations of the effects of electron-electron interactions in graphene by magneto- Raman scattering experiments in which we probe inter- Landau-level (LL) excitations in a monolayer graphene subject to a magnetic field will be reported. Three graphene systems with distinct dielectric environments have been studied. The non-interacting Dirac-like description of electronic states largely fails to account for the full set of our experimental observations. Instead, the experiment is fair agreement with the theoretical model which takes into account both self energy and vertex corrections to inter Landau level excitations.

Frédéric Piéchon ,LPS, Orsay
A. Raoux, M. Morigi, F. Piéchon, J-N. Fuchs et G. Montambaux

Orbital magnetic susceptibility of multiband systems.

Although being an equilibrium property, the orbital magnetic susceptibility is a complex quantity because, contrary to transport quantities, it involves the full energy spectrum and the structure of the wave functions. Beyond the simplest Landau picture valid for free electrons, the generalization proposed by Peierls is valid for a single band and cannot describe multiband systems, like graphene which is known to exhibit a diverging diamagnetic response at the Dirac point. In this talk we review recent results that show the importance of band structure and interband effects (Berry curvature) on the orbital magnetic response of Bloch electrons in metals and insulators. Beyond the simplest examples of graphene and boron-nitride, we review recent simple models in which the coupling between bands can be tuned. We present a simple example where two systems having the same energy spectrum exhibit a totally different magnetic response.

Norio Kumada, NTT Basic Research Laboratories
N. Kumada, F. D. Parmentier, H. Hibino, D. C. Glattli, and P. Roulleau

Shot noise generated by graphene p-n junctions in quantum Hall effect regime

In graphene bipolar quantum Hall states, counter circulating edge modes for electrons and holes mix at the p-n junction (PNJ). We show that the mode mixing and the subsequent partitioning at the exit of the PNJ generate shot noise. This demonstrates that the PNJ can serve as a beam splitter of electrons and holes. We also show that the energy relaxation in the mixed modes by changing the length of the PNJ. These findings unveil beam splitter properties in graphene, making graphene an excellent candidate for electron quantum optics experiments.

K. Zimmermann, Institut Néel, Grenoble
K. Zimmermann, A. Jordan, K. Watanabe, T. Taniguchi, F. Gay, V. Bouchiat, B. Sacépé

Quantum point contact in graphene in the quantum Hall regime

We have fabricated ballistic graphene devices made by van der Waals stacking of hBN/Gr/hBN heterostructures, and equipped with split gates forming a quantum point contact (QPC) constriction. In the quantum hall regime, the spin and valley degeneracies are fully lifted and fractional quantum Hall plateaus are observed. Unlike disordered p-n junctions in the quantum Hall regime, the full degeneracy lifting protects the quantum Hall edge channels against equilibration at the p-n interface induced by the split gate. Thus, varying the split gate potential of the QPC enables a continuous selection of the transmitted integer and fractional edge channels through the constriction, up to full pinch-off. Our findings demonstrate that high mobility graphene can serve as a new platform for the control and manipulation of coherent transport through quantum Hall edge channels.

Session : systèmes 1D

Guillaume Gervais, McGill University
G. Gervais, D. Laroche, M.P. Lilly and J.L. Reno

Traînée de Coulomb 1D-1D dans les fils quantiques verticalement couplés

Traînée de Coulomb 1D-1D dans les fils quantiques verticalement couplés Je vais présenter nos expériences sur la traînée de Coulomb entre deux circuits électroniques unidimensionnels [1] et ensuite discuter des implications par rapport aux divers modèles théoriques (mésoscopiques, phonons et fortes corrélations). Une emphase sera mise sur la physique de l'inter-couplage des ondes de densité de charge prédite dans les modèles de liquide de Luttinger [2,3] et ces derniers seront discutés en profondeur. Si le temps le permet, le système analogue d'un fil quantique mais pour un système neutre où le transport est un écoulement de masse vous sera décrit et des résultats expérimentaux récents seront présentés.

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Zoran Ristivojevic, LPT, Toulouse

Decay rates of quasiparticles in one-dimensional quantum liquids

During the last several decades, one dimensional systems of spin chains and interacting bosons and fermions are conventionally studied within the Luttinger liquid theory. It assumes strictly linear dispersion of excitations. While being very fruitful in describing low-energy phenomena, it has important limitations, as, for example, it cannot describe the decay of excitations. In this talk I will consider this problem in fermionic and bosonic systems. At zero temperature, a fermionic quasiparticle decays with the rate proportional to the eight power of its momentum (measured from the Fermi surface). On the other side, a bosonic quasiparticle decays with the rate proportional to the seventh power of its momentum. At non-zero temperature, the decay rates may become affected. For special models of interacting fermions and bosons that are integrable, the quasiparticle decay rate vanishes.

"Decay of Bogoliubov quasiparticles in a nonideal one-dimensional Bose gas" Z. Ristivojevic and K. A. Matveev Phys. Rev. B 89, 180507(R) (2014).
"Relaxation of weakly interacting electrons in one dimension" Z. Ristivojevic and K. A. Matveev Phys. Rev. B 87, 165108 (2013).
"Excitation spectrum of the Lieb-Liniger model" Z. Ristivojevic Phys. Rev. Lett. 113, 015301 (2014).

Jeudi 4 décembre 2014

Session : Boîtes et points quantiques supraconducteurs

David van Zanten, Institut Néel, Grenoble
D.M.T. van Zanten, D.M. Basko, H. Courtois, C.B. Winkelmann

Quantized charge pumping through superconductor - quantum dot - superconductor hybrids

Single electron pumps are foreseen to set the new quantum standard for current, thereby closing the quantum metrology triangle. During the past decade, signicant experimental and theoretical eort has been spent on a variety of mesoscopic systems. Here we demonstrate quantized charge pumping in superconductor - quantum dot - superconductor hybrid turn- stiles. The quantum dot devices are formed by single gold nano-particles inserted in electromigrated aluminium constrictions. Charging energies and single level spacings are much larger than the superconducting gap, which allows charge pumping through a single electron level. The turnstiles are op- erated at pumping frequencies up to 200 MHz and reach an accuracy of ~1%. We discuss the accuracy limitation set by the lead-quantum hybridiza- tion and pair currents through the dot. Conversely we show that the large level spacing protects the pumping accuracy from thermally induced errors over a large temperature range.

Raphaëlle Delagrange, LPS, Orsay
Raphaëlle Delagrange, Raphaël Weil, Alik Kasumov, Hélène Bouchiat, Richard Deblock

Evidence of phase dependent Kondo screening in a carbon nanotube Josephson junction

When a localized magnetic moment interacts with a Fermi sea of delocalized conduction electrons, Kondo effect can take place. Thanks to spin-flip processes, a many-body singlet state is formed, screening the magnetic moment. However, in the presence of another effect energy scale in the system such as a superconducting gap Δ, this screening can be suppressed due to the competition between Kondo and superconductivity. This situation can be investigated using quantum dots based hybrid junction, here a carbon nanotube contacted to superconducting leads, where the number of electrons (and thus the magnetic moment) in the dot is controlled by a gate voltage. Then, inserting the system in a SQUID (Superconducting Quantum Interference Device) [3], another parameter can be introduced: the superconducting phase of the junction. Generally, the Andreev states in a hybrid junction depend on this superconducting phase, giving rise to the current-phase relation for the Josephson current. More surprisingly, for the intermediate regime $\Delta \sim T_K$, Kondo screening is predicted to depend also of the phase [1,2], meaning that the effective moment of the Quantum dot can be tuned by the phase across the junction. In this work, we have succeeded for the first time to measure this Kondo effect controlled by the superconducting phase difference and we compare it to theoretical predictions.

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Rémi Avriller, LOMA, Bordeaux
Rémi Avriller et Fabio Pistolesi

Washing out of the 0-pi transition in Josephson junctions

We consider a Josephson junction formed by a quantum dot connected to two bulk superconductors in presence of Coulomb interaction and coupling to both an electromagnetic environment and a finite density of electronic quasi-particles. In the limit of large superconducting gap we obtain a Born-Markov description of the system dynamics. We calculate the current-phase relation and we find that the experimentally unavoidable presence of quasi-particles can dramatically modify the 0-pi standard transition picture. We show that photon-assisted quasi-particles absorption allows the dynamic switching from the 0- to the pi-state and vice-versa, washing out the 0-pi transition predicted by purely thermodynamic arguments.

Preprint available on arXiv:1407.5561 (2014)

Camille Janvier, Quantronics group, SPEC, Saclay
Camille Janvier, Leandro Tosi, Caglar Girit, Michael Stern, Denis Vion, Daniel Esteve, Marcelo Goffman, Hugues Pothier, Cristian Urbina

Coherent manipulation of Andreev bound states

When two superconductors are linked through a weak link, two energy levels appear on the link within the superconducting gap. These so called Andreev bound states constitute the ground and excited states of a single pair on the weak link. While in a bulk superconductor twice the gap energy is needed to drive the lowest energy excitation of a pair, here the excitation energy ca be much smaller and is determined by the transmission of the conduction channel and the difference of superconducting phases across the link. This system constitutes a microscopic two-level system with excitation energy which can be accessed with microwave techniques. Here we present our results on the coherent manipulation of this two-level system. An atomic contact obtained with a mechanically controllable break junction is used as a weak link. It is placed in a superconducting loop and coupled to a microwave resonator. This standard circuit-QED architecture allows to perform single shot measurements of the state of the localized pair, and to manipulate coherently its quantum state as illustrated by Rabi oscillations, Ramsey sequences and spin echoes.

Roman-Pascal Riwar, INAC/SPSMS, Grenoble
Roman-Pascal Riwar, Manuel Houzet, Julia S. Meyer, and Yuli V. Nazarov

Control of Andreev bound state population and related charge-imbalance effect

Motivated by recent experimental research, we study the processes in an ac driven superconducting constriction whereby one quasiparticle is promoted to the delocalized states outside the superconducting gap. We demonstrate that with these processes one can control the population of the Andreev bound states in the constriction. We stress an interesting charge asymmetry of these processes that may produce a charge imbalance of accumulated quasiparticles, which depends on the phase.

Preprint on arXiv:1407.0534

Session : Supraconductivité en dimensions réduites

Christophe Brun, Institut des Nanosciences de Paris
L. Serrier-Garcia, V. Cherkez, C. Brun, T. Cren, J. C. Cuevas, F. Debontridder, S. Pons, D. Fokin, V. S. Stolyarov, F. S. Bergeret, M. C. Tringides, S. Bozkho, L. Ioffe, B. L. Altshuler, and D. Roditchev

Proximity effect at the 2D limit and monolayer superconductivity : new insight from local probes

The possibility of growing in situ ultrathin single crystal superconducting nanostructures, and studying their local spectroscopic properties by scanning tunneling spectroscopy, allowed us to reveal the fascinating phase diagram of confined superconductors with unprecedented details [1]. The nanostructures under investigation are grown in ultrahigh vacuum on a silicon substrate and studied at 300mK under magnetic field by in situ scanning tunneling spectroscopy/microscopy (STS/STM). Extending previous spatially resolved studies of the proximity effect [2], we will present a spatially resolved study of the proximity effect between Pb superconducting islands and a highly diffusive two-dimensional metal, consisting of the Pb wetting layer covering the entire silicon surface. We show that it is possible to model phenomenologically the experimental spectra by coupling the Usadel equations, describing the proximity effect toward a diffusive metal, to dynamical Coulomb blockade phenomenon describing the correlated properties of the 2D disordered metal layer [3]. In a complementary way, we will show that it is possible to grow crystalline atomic monolayers of Pb on Si(111), which are superconducting below 2K [4], and to study the spatially resolved proximity effect between two superconductors of different energy gaps [5]. Finally, we have investigated the intrinsic electronic properties of two structurally different Pb/Si(111) monolayer superconductors. It is well known that conventional superconductivity is very robust against non-magnetic disorder. Such single crystal monolayers are well-controlled and tunable system to probe and study the influence of various types of structural defect on the superconducting properties. Our study by very-low temperature STM (300mK) under magnetic field reveals unexpected new results involving spatial spectroscopic variations at length scale much smaller than the superconducting coherence length [6]. Our results show that monolayer systems with square resistance not close to the resistance quantum should be described by a model incorporating significant non-BCS corrections. Furthermore, strong local evidence of the signature of the Rashba effect on the superconductivity of one of the Pb/Si(111) monolayer system is revealed. Finally the structural and electronic differences between the two monolayer systems lead to very different properties of the vortices.

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[6] C. Brun, T. Cren et al. Nature Physics 10, 444 (2014), arXiv:1401.7876

Eduard Driessen, INAC/SPSMS, Grenoble
E.F.C. Driessen, C. Chapelier, P.C.J.J. Coumou, and T.M. Klapwijk

Microwave electrodynamics and local tunneling spectroscopy of strongly disordered superconducting thin films

We have studied the electrodynamic response of strongly disordered TiN and NbTiN films, close to the superconductor-insulator transition, by making the superconducting film the resonating element of a high-quality coplanar waveguide resonator at GHz frequencies. We study the temperature dependence of the resonator response, and find that with increasing disorder, the response increasingly deviates from conventional Mattis-Bardeen theory. Our measurements are well described with a uniform model of the superconducting state, using an effective pair breaker analogous to the effect of magnetic impurities, yielding a rounded-off quasiparticle density of states. The effective pair breaker needed to describe our measurements increases with increasing disorder. We compare these observations to local scanning tunnelling spectroscopy on the same films. For the least-disordered film ($k_F l = 8$), we find good agreement between the electrodynamics and the STS measurements. This indicates that disorder has already a pronounced influence on the superconducting state far away from the SIT, in contrast to what is commonly believed. For the most-disordered film, kFl = 0.8, we find an inhomogeneous superconducting state, with larger coherence peaks and a steeper gap edge, than predicted from the electrodynamics measurement. This calls for a better theoretical understanding of the electrodynamics of strongly disordered superconductors.

E.F.C. Driessen et al., Phys. Rev. Lett. 109, 107003 (2012);
P.C.J.J. Coumou et al., Phys. Rev. B 88, 180505 (2013).

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Top gating control of superconductivity at the LaAlO3/SrTiO3 interfaces

Transition metal oxides display a great variety of quantum electronic behaviors where correlations often play an important role. The achievement of high quality epitaxial interfaces involving such materials gives a unique opportunity to engineer artificial materials where new electronic orders take place. It has been shown recently that a superconducting two-dimensional electron gas 2DEG could form at the interface of two insulators such as LaAlO3 and SrTiO3 [1], or LaTiO3 (a Mott insulator) and SrTiO3 [2]. An important feature of these interfaces lies in the possibility to control their electronic properties, including superconductivity and spin-orbit coupling with field effect [3-5]. However, so far, experiments have been performed almost exclusively with a metallic gate at the back of the substrate, which makes difficult to control these properties on the mesoscopic scale. We present transport and magneto-transport measurements in top-gated micron-size structures designed in the LaAlO3/SrTiO3 interfacial 2DEG using an original technique that combines lithography and ion implantation. We show that superconductivity and spin orbit coupling can be tuned over a wide range by applying a top gate voltage. This result paves the way for the realization of mesoscopic devices.

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Session : Systèmes nanomécaniques

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Resonant dynamics of a spin-nanomechanical hybrid system

We present the dynamics of a hybrid spin-nanomechanical system based on a single NV defect in diamond and a SiC nanowire. When the spin precession frequency approaches the vibration frequency, a synchronization of the spin dynamics onto the mechanical motion is experimentally observed. It can be understood as a phononic Mollow triplet signature. We investigate the role of mechanical dissipation in this process and the possibility to protect the spin from decoherence due to the Brownian motion of the nanoresonator.

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Ultrashort single-wall carbon nanotubes reveal field-emission Coulomb Blockade and highest electron-source brightness

In-situ field emission (FE) measurements of electrons directly emitted from SWCNT cantilevers (see Fig. up) grown in a field emission (FE) microscope [1] are presented that show strong, multiple Coulomb Blockade (CB) oscillations [2]. This is the first time that FE has been used to observe a CB staircase and the measurements are in quantitative agreement with theory [3]. Since Likharev pointed out in his seminal review [4] that the low temperatures and low currents of CB based devices represent bottlenecks for their integration, a continual effort has been made to increase both during device operation [5]. Current steps were detected here in the 300K-1100K temperature range and up to 1.8µA, considerably higher than values reported in the literature. Residence of individual additional electrons on the SWCNT was detected independently both in the FE current and in the mechanical resonance eigenfrequency as a function of applied voltage, the later being similar to recent results in the transistor configuration [6]. In-situ controlled shortening of our samples allowed us to increase the period of the oscillations progressively from 5.5 to 80 Volts and at the same time to decrease the smallest detectable additional charge on the SWCNT from about 33e down to about 7e. This process led to the brightest electron source ever reported (9*1011A/(str*m2*V)), having a potential interest to a wide range of scientists working both in technological applications, such as electron-based microscopy and lithography, or in fundamental quantum electron transport physics (egs. SETs, memory storage, coherent single-electron sources)

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POSTER ABSTRACTS

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Diffusion of Dirac fermions in presence of spin-orbit impurities

The recent realization of 3 dimensional topological insulators allows to probe the coherent transport of Dirac systems. Dirac fermions in presence of a random disorder potential is a model that can not explain all the features seen in magnetoconductance experiments, for example the weak anti-localization (WAL) correction observed is smaller than expected. It has ben proposed that there could be a coupling of the surface states with the bulk states [1], but the influence of the spin-orbit impurities has not been studied. In [2] Hikami, Larkin and Nagaoka derived a formula concerning the diffusion of conventional electrons in presence of spin-orbit impurities, showing that we observe a crossover from weak localization to WAL as the spin-orbit impurities concentration increases. In this work, we derive with the standard diagrammatic technique [2,3] the quantum correction to conductivity when we add spin-orbit impurities to the diffusion of Dirac fermions in a disordered potential, and show that for every value of the spin-orbit coupling we remain in the symplectic class of WAL. We also give the expected value of this quantum correction to conductivity as a function of the transverse magnetic field.

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Majorana Bound States in wires and ribbons

In the pursuit of Majorana Bound States (MBS), we consider recent proposals for their realization in a wire of magnetic atoms on the surface of a superconductor. Coupling wires to form ribbons, we study how these sates are enhanced or killed. We compare the equivalency of these systems and those with Zeeman and spin-orbit interaction. We quantify the Majorana Polarization which was shown to be a useful tool for identifying MBS in linear chains with Rashba spin-orbit interaction.

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Fluctuation-dissipation relations of a tunnel junction driven by a quantum circuit

We derive fluctuation-dissipation relations for a tunnel junction driven by a high impedance microwave resonator, displaying strong quantum fluctuations. We find that the fluctuation-dissipation relations derived for classical forces hold, provided the effect of the circuit's quantum fluctuations is incorporated into a modified non-linear I(V) curve. We also demonstrate that all quantities measured under a coherent time-dependent bias can be reconstructed from their dc counterpart with a photo-assisted tunneling relation. We confirm these predictions by implementing the circuit and measuring the dc current through the junction, its high frequency admittance and its current noise at the frequency of the resonator.

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Andreev-Bragg reflection from an Amperian superconductor

We show how an electrical measurement can detect the pairing of electrons on the same side of the Fermi surface (Amperian pairing), recently proposed by Patrick Lee for the pseudogap phase of high-T_c cuprate superconductors. Bragg scattering from the pair-density wave introduces odd multiples of $2k_F$ momentum shifts when an electron incident from a normal metal is Andreev-reflected as a hole. These Andreev-Bragg reflections can be detected in a three-terminal device, containing a ballistic Y-junction between normal leads (1,2) and the superconductor. The cross-conductance dI_1/dV_2 has the opposite sign for Amperian pairing than it has either in the normal state or for the usual BCS pairing.

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Electrical detection and manipulation of a single nuclear spin

Recent advances in addressing isolated nuclear spins have opened up a path toward using nuclear-spin based quantum bits. Local magnetic fields are normally used to coherently manipulate the state of the nuclear spin; however, electrical manipulation would allow for fast switching and spatially confined spin control. Here, we propose and demonstrate coherent single nuclear spin manipulation using electric fields only. Because there is no direct coupling between the spin and the electric field, we make use of the hyperfine Stark effect as a magnetic field transducer at the atomic level. This quantum-mechanical process is present in all nuclear spin systems, such as phosphorus or bismuth atoms in silicon, and offers a general route toward the electrical control of nuclear-spin based devices.

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Theoretical, numerical, and experimental study of a flying qubit electronic interferometer

We discuss an electronic interferometer recently measured by Yamamoto et al. This “flying quantum bit” experiment showed quantum oscillations between electronic trajectories of two tunnel-coupled wires connected via an Aharanov-Bohm ring. We present a simple scattering model as well as a numerical microscopic model to describe this experiment. In addition, we present experimental data to which we confront our numerical results. While our analytical model provides basic concepts for designing the flying qubit device, we find that our numerical simulations allow us to reproduce detailed features of the transport measurements such as in-phase and antiphase oscillations of the two output currents as well as a smooth phase shift when sweeping a side gate. Furthermore, we find remarkable resemblance for the magnetoconductance oscillations in both conductance and visibility between simulations and experiments within a specific parameter range.

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Influence of temperature on destructive quantum interferences in anthraquinone based junctions

Due to their small dimensions, molecules are very promising nano-objects that can be used as basic elements of electronic components such as wires, rectifiers, switches. As in any nano-system, quantum effects are expected to dominate charge transport in molecules. It has been predicted theoretically that if a cross conjugated molecule is connected between two metallic contacts it may behave as a quantum interferometer: electrons can pass through the molecule by two phased opposed paths defined by the localized molecular orbitals and interfere destructively. This phenomenon results in a reduction of the transmission function, with a clear anti-resonance at the energy where interferences occur. Such characteristics results experimentally in the presence of a dip in the junction conductance measured as a function of the voltage bias applied between the electrodes. Recently, we have observed this effect in large area molecular junctions based on anthraquinone (AQ), the prototype of cross conjugated molecule. Our devices are built by combining nanofabrication processes and electrochemical grafting of the molecules. Here, we will show a study of the temperature’s influence on quantum interferences in AQ based junctions. Our results show a strong temperature dependence of the zero bias conductance and the occurrence of extra-structures in the conductance curve at low energy and low temperature. Our observations are consistent with recent theoretical calculations predicting the suppression of quantum interferences by increasing temperature and by taking into account electron-phonon coupling. Quantum interferences are also expected to be responsible for a giant Seebeck effect, i.e. a drastic enhancement of the thermopower around the transmission node, expected to reach a universal temperature independent maximum value of ~±156µV/K. This issue is extremely interesting for direct conversion of electrical energy into thermal energy. We will address the technical challenges required to get an experimental evidence of enhanced thermoelectric in anthraquinone based junctions.

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Transport through functionalized multiwall carbon nanotubes contacted with ferromagnetic electrodes

Carbon-based materials1 were found to be promising for an integration in hybrid spin electronics devices. The original idea was that long spin lifetimes are expected in such light materials and thus, they could be used to store and/or to propagate the spin information. This property is due to weak spin scattering as spin-orbit coupling is almost absent and due to transport occuring through л-orbitals insensitive to nuclear spin. In carbon nanotubes (CNT) and graphene2, it was experimentally highlighted by the reports of long spin diffusion lengths (>50µm) also helped by high carrier mobilities in those materials. In this paper, we will present transport experiments performed at low temperatures on multiwall carbon nanotubes in which the external shell is functionalized with organic molecules (Bis-Thienyl Benzene). This chemical functionalization is realized in solution with diazonium-based radical species which react with the nanotube to form a stable C-C bond3. By changing the sp2 configuration into a sp3 of the outter shell, its electronic properties is also changed and charges are more pushed towards the inner shells which transport properties are usually not probed. We will in a first part describe the fabrication process illustrated with an AFM study of the different interfaces (nanotube/molecules and ferromagnetic/molecules on nanotubes). In a second part, we will present transport experiments comparing transport through clean multiwall nanotubes unveiling pseudo-gap sub-structures4 at low bias voltages and through functionalized ones in which we observe strong oscillations of conductance. We will discuss about the possible origin of those oscillations.

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The dark side of plasmonic decay in a metallic nanoparticle dimer

Plasmonic metamaterials have attracted over the last years enormous interest due to their potential applications in, e.g., manipulating and guiding light a subwavelength scales ("plasmonic circuitry"). In particular, metameterials based on ordered arrays of metallic nanoparticles are intensively studied. However, one of the main limitation of these metamaterials are the losses encountered by the plasmonic excitations they sustain. It is therefore of paramount interest to understand in detail the damping mechanisms at work in such plasmonic metamaterials. In this work, we theoretically consider a metallic nanoparticle dimer which can serve as a building block of more complex and extended plasmonic arrays. We investigate the damping of the bright and dark plasmonic modes resulting from the near-field coupling between the two nanoparticles. In particular, we provide analytical expressions for the frequencies and decay rates of the bright and dark plasmonic modes. We show that, for sufficiently small nanoparticles, the main decay channel for the dark plasmonic mode, which is weakly coupled to light and, hence, immune to radiation damping, is of nonradiative origin and corresponds to Landau damping, i.e., decay into electron-hole pairs.

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Quantum dynamics of an electromagnetic mode that cannot have N photons

Electromagnetic modes are instrumental for realizing quantum physics experiments and building quantum machines. Their manipulation usually involves the tailoring of their Hamiltonian in time. An alternative control scheme, called Quantum Zeno Dynamics (QZD), consists in restricting the evolution of a mode to a subset of possible states [1]. This promising control scheme has been implemented earlier this year on atomic levels of Rb [2] and of a Rydberg atom [3]. In this talk, I will report the first observation of QZD of light, using superconducting circuits. By preventing the access to a single energy level, the dynamics of the field is dramatically changed [4]. Here, it was possible to avoid a number of photons N, which was arbitrarily chosen between 2 and 5. Under this constraint, and starting in its ground state, a resonantly driven mode is confined to levels 0 to N-1. The level occupation is then found to oscillate in time, similarly to an N-level system. Performing a direct Wigner tomography of the field reveals its non-classical features. In particular, at half period in the evolution, it resembles a "Schrédinger cat state". All these observations are well captured by a model based on N levels only. Our results demonstrate that QZD allows the direct control of the field state in its phase space. This experiment paves the way to the realization of various protocols, such as phase space tweezers [4], generation and protection of entanglement, and quantum logic operations.

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Dynamics of Kondo effect at finite frequency

We measure the conductance of a quantum dot in the Kondo regime under microwave excitation. We observe a decrease in the conductance at the Kondo resonance and the appearance of satellite peaks in agreement with previous work [1]. Thanks to an in situ microwave power calibration, we realize the first study on the frequency dependence of those features. The suppression of the Kondo conductance as microwave power increases is weaker for the highest frequencies. This result agrees with the theoretical prediction [2] in the case of microwave coupling to the leads.

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Possible Kondo phase shift in quantum point contacts probed by scanning gate microscopy

Quantum point contacts (QPCs) are among the most simple devices in nano-electronics, but still remain mysterious after 25 years of intense studies. In textbooks, these quasi one-dimensional ballistic channels are described as electron wave-guides: more and more transverse modes are transmitted when the QPC opens, and its conductance evolves by quantized steps of the conductance quantum. However, QPCs always show puzzling deviations from this simple picture, attributed to electron-electron interactions. The most famous one is the "0.7 anomaly", an unexpected additional plateau around 0.7 x $2e^2/h$. In this work, we focus on the "zero bias anomaly", a zero bias peak in the differential conductance that arises at very low temperature below the first conductance plateau. This peak has been proposed to be a signature of the Kondo effect (Cronenwett 2002), but its temperature and magnetic field dependence have often been reported as inconsistent with the Kondo effect known in quantum dots. Moreover, its debated Kondo origin has been recently put in the forefront of the scene (Iqbal 2013, Bauer 2013, Brun 2014), and the problem appears far from being solved. As usual conductance measurements fail to solve unambiguously this question, we propose to carry out phase sensitive measurements to give new types of information on this effect. Using scanning gate microscopy (SGM), we can realize an interferometric experiment and try to detect the universal phase shift experienced by electrons scattering off a Kondo singlet. We use the negatively polarized tip of an atomic force microscope at very low temperature, and create a Fabry-Pérot interferometer between the QPC and the tipdepleted region. As a result, we find that the zero bias anomaly induces a clear phase-shift of the observed interferences while sweeping the source-drain bias. This phase-shift evolves with temperature and gate voltage exactly as the zero bias peak does. If this observed phase-shift corresponds to the expected universal scattering phase off a Kondo singlet, our result may definitely attribute the origin of the zero bias anomaly in QPCs to the Kondo effect.

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Probing Spin-Dependent Recombination at High Rabi Frequencies

We probe spin-dependent recombination in photovoltaic blends at low temperatures using the electron spin resonance response of a superconducting resonator [1]. For low AC magnetic fields, the usual spin one-half response is recovered, while for high driving fields a qualitatively different behavior is seen where we find a distinctive splitting, characterized by the Rabi frequency. We explain our results as arising from the spin-dependent recombination of electron-hole pairs, and present simulations which allow quantitative modeling of the observed behavior.

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Spin accumulation in out of equilibrium mesoscopic superconductors

We study the spin accumulation in a junction between a superconductor and a ferromagnet or a normal metal in presence of a Zeeman magnetic field applied to the superconductor, and when the junction is taken out of equilibrium by applying a voltage bias. We first apply a DC voltage on the junction and show that the spin relaxation time (~ns) is larger than the charge relaxation time (~ps) inducing a spin-charge separation in the superconductor. Then we calculate the time-dependence of the spin accumulation for an applied AC voltage. We find that the measured spin accumulation depends on the frequency of the applied bias. This dependence allows one to extract directly the spin relaxation time in the superconductor which is in complete agreement with the experimental result.

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Superconducting silicon micro and nano devices

Even though silicon is one of the most studied materials, superconductivity at ambient pressure in boron doped silicon has only been discovered in 2006 [1]. This is due to the extreme doping concentration required to trigger superconductivity in this system (> 1 at. %), a threshold larger than the boron solubility limit in silicon. This concentration is impossible to reach using conventional micro-electronic techniques, but epitaxial superconducting Si:B thin films can be achieved using Gas Immersion Laser Doping. Superconducting silicon is a hole BCS superconductor, whose critical temperature can be tuned up to 0.7 K by varying the boron dose [2]. Taking advantage from the silicon technology, micro and nano devices can be elaborated in a single Si crystal from superconducting, metallic and semiconducting silicon regions, coupled through extremely clean, epitaxially grown interfaces. We demonstrate the possibility of nano-structuring the strongly boron-doped Si without affecting its properties, realising all silicon Superconductor-Normal metal Josephson junctions and coplanar waveguides. Both systems are well understood in the frame of standard metallic superconductor systems, and open the road to the exploitation of the silicon semiconducting properties, such as the gate-tunability (gated Josephson junctions as JoFET) or the high resistivity coupled to a low Tc (high kinetic inductance).

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Silicon CMOS electron pumps: performances, integrated circuit and deep-UV version

With the foreseen new definition of the Ampçre, there is a need for electron pumps to realize this quantum definition based on the electron charge, which will be fixed (together with the Planck constant h). This will create a consistent set of quantum-based electrical units, together with the Volt and Ohm already realized since 1990 in metrology institutes with the Josephson and Quantum Hall effects. For this goal the Si-MOSFET based electron pump developed at CEA Grenoble (one island, two tunable barriers, see Ref [1]) has proven its efficiency and now needs to be tested in a metrological environment. In parallel we designed with CEA-Leti an electronic circuit which delivers the RF signal on-chip, thanks to a ring-oscillator and a non-overlapping clocks generator. We have observed rectification, in good agreement with modeling [2]. More recently we have fabricated a full deep-UV made set of devices which shows for the first time electron pumping without electron-beam lithography [3]. This has been obtained thanks to long offset spacers which decreases the size of the central island. Interestingly, unlike most electron pumps in which applying a source-drain bias is always detrimental, the robustness of the barriers of our devices is such that applying a bias can actually improve the quantized plateaus.

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A Silicon Artificial Atom

The fabrication of quantum dots with true artificial atoms (AA) behavior in silicon is very challenging due to the large density-of-states and short mean free path: one should reach dimensions of the order of 5nm to reach this goal. We fabricated silicon Field-Effect-Transistors (FETs) with extremely small dimensions (3.4nm diameter and 10nm gate length) and tunnel barriers realized by long offset spacers (25nm) to isolate the dot from the leads. In that way the leads are non-invasive, while keeping a good electrical connection to the dot. A relatively thick (7nm) gate oxide provides a good electrostatic control and enhances the Coulomb repulsion between carriers. Such devices exhibit strong carrier confinement, with addition energies ranging from 70meV to 250meV. From spectroscopy measurements, we identified an excited state 5meV above the ground state due to Valley-Orbit splitting. The data are compared with Non-equilibrium Green's function simulations using the realistic 3D structure. A good qualitative agreement is found, and we emphasize the relatively weak impact of the disorder, namely the surface roughness, on the results, as well as a large mean level orbital splitting of 30meV. We acknowledge support from the EU projects TOLOP and SiSPIN.

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Josephson vortex cores: From direct imaging to an all-electronic control

Superconducting correlations may propagate between two superconductors separated by a tiny insulating or metallic barrier, allowing a dissipationless electric current to flow. In presence of magnetic field, the maximum supercurrent oscillates, each oscillation corresponding to the entry of one Josephson vortex into the barrier. Josephson vortices are conceptual blocks of advanced quantum devices such as coherent THz generators or qubits for quantum computing, in which their on-demand generation and control is crucial. Here, we map superconducting correlations inside proximity Josephson junctions using scanning tunneling microscopy. Unexpectedly, we find that such Josephson vortices have real cores, in which the proximity gap is locally suppressed and the normal state recovered. By following the Josephson vortex formation and evolution we demonstrate that they originate from quantum interference of Andreev quasiparticles, and that the phase portraits of the two superconducting quantum condensates at edges of the junction decide their generation, shape, spatial extent and arrangement. Our observation opens a new way of generation and control of Josephson vortices by applying supercurrents through the superconducting leads of the junctions, i.e. by purely electrical means without any need for a magnetic field, a crucial step towards high-density on-chip integration of superconducting quantum devices.

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Topological insulator Josephson junctions: from geometrical to topological effects

Novel excitations are predicted to emerge at the interface between a superconductor and a topological insulator [1]. They are zero-energy excitations called Majorana bound states and rely on the existence of a topologically protected mode which is perfectly transmitted. We however expect that this topologically protected mode can be unveiled only in a nanowire geometry, where confinement reduces the number of modes. Recent experiments [2,3], made in microstructures with a large number of modes, have not shown conclusive evidence of the existence of such a mode. Quantum transport properties of nanowires of Bi_2Se_3 has been studied recently in our group [4]. These nanowires, which host only a dozen of modes, are the ideal platform to test the existence of a topologically protected mode. We plan to independently measure the set of transmissions of a topological insulator nanowire and the current-phase of a topological insulator Josephson junction. It would be possible to perform a tunnel spectroscopy experiment afterward, thus revealing the states hosted by a topological insulator Josephson junction.

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Real time decoherence of Landau and Levitov quasi-particles in quantum Hall edge channels

Quantum Hall edge channels at integer filling factor provide a unique test-bench to understand decoherence and relaxation of single electron excitations in a ballistic quantum conductor. I will present a full visualization of the decoherence scenario of energy (Landau) and time (Levitov) resolved single electron excitations at filling factor ν, showing that the Landau excitation exhibits a fast relaxation followed by spin-charge separation whereas the Levitov excitation only experiences spin-charge separation. I will explain how Hong-Ou-Mandel type experiments can be used to probe specific signatures of these different scenarios. I will finally discuss how to control decoherence within this framework.

arXiv:1403.8047, To appear in Phys. Rev. Lett.

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Topological properties of periodically driven systems

Periodically driven systems exhibit unusual topological properties, with no equivalence in equilibrium phases. Novel topological invariants can be defined and related to protected boundary states, in particular when the driven system is constrained by symmetries.

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Microwave cavities as a probe of Kondo physics and Majorana fermions

We couple carbon nanotube based electronic circuits to microvave photon cavities. The dispersive shift of the cavity fequency gives us access to the charge susceptibility of a quantum dot connected to fermionic leads [1]. We deduce the quantum capacitance and dissipation of the dot by measuring the complex transmission of the cavity. Hence we achieve a direct probing of the charge dynamics of the dot. This could be of special interest for Kondo regime, where spin and charge dynamics of the dot are expected to be decoupled [2].To get a significant coupling between the quantum dot and the microwave photons, we stamp carbon nanotube over Al buried back gate, that is capacitively coupled of the central line of the microvave resonator. We also plan to use Ni buried gate, that presents naturally a magnetic texture, in order to engineer an artificial spin-orbit coupling in the nanotube. This spin orbit coupling is a key ingredient for the implementation of Majorana fermions in a 1D topological superconductor. The cavity transmission could then be a direct signature of the self-adjoint property of these Majorana fermions, hosted at the ends of the carbon nanotube [3].

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Charge susceptibility in a resonant quantum RC circuit

There have been a lot of experimental work in the past couple of years on integrating microwave electromagnetic cavities with quantum dots. Such devices allow exploring the new physics at the interface between cavity QED and mesoscopic physics. In this work, we study the coupling between the cavity and the quantum dot, focusing on the photonic degrees of freedom in order to elucidate the transport properties of the quantum dot. We access the charge degrees of freedom by resorting to the input-output theory for the photonic modes. More specifically, the cavity modes probe directly the charge susceptibility of the QD: the reduction of the output signal compared to the input one gives information about the imaginary part of the charge susceptibility, while the phase shift gives access to the real part of the susceptibility.

Clément Dutreix
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Spin-Singlet Superconductivity and Majorana Modes in the Honeycomb Lattice

Spin-singlet superconductors are known to manifest Majorana boundary modes in the presence of Rashba spin-orbit interactions, when a Zeeman magnetic field breaks the time-reversal symmetry [1-4]. The possible existence of such boundary modes, which is connected to topological properties of the band structure [4], is investigated here in the honeycomb lattice. Different from monatomic lattices, which are what the literature essentially focuses on, the Majorana-mode emergence in a honeycomb lattice explicitly depends on the magnitude of the spin-orbit coupling. Thanks to the inversion symmetry, we are able to characterise the band-structure topology of this eight-band two-dimensional system with broken time-reversal symmetry. Therefore, we can predict the emergence of chiral Majorana modes at the edges of doped and strained nanoribbons.

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Subgap conductances in three terminal SNS Josephson junctions under microwave irradiation

In a recent paper (A. H. Pfeffer et al., Phys. Rev. B 90, 075401) we have shown that new subgap features appears in three terminal Josephson junctions. Those appear as Josephson-like resonances are observed in the differential conductance when the voltages applied between two superconducting contacts compensate each other. These resonances are consistent with the prediction of non-local quartets as the result of double crossed Andreev reflections at one superconducting contact. To complete the description of these quartet resonances, we have studied the subgap response of the exact same type of samples under microwave irradiation. In a 2D plot, integer and half integer vertical and horizontal Shapiro lines are seen as the result of the synchronization between the microwave signal and the two-terminal AC Josephson effect. In addition, the quartet lines are also split. This observation reveals that the quartet mechanism is indeed a coherent mechanism that involved the three superconducting terminals. A simple phenomenological model based on the RSJ description of diffusive three-terminal SNS junctions has been developed and give a rather intuitive understanding of our results. A more microscopic theory is under investigation.

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Manipulation of Andreev bound states in unconventional Josephson junctions

We study a Josephson junction between a conventional s-wave superconductor and an unconventional p-wave superconductor. The junction has two spin-polarized Andreev bound states, giving rise to a spontaneous magnetization at zero temperature. In equilibrium, the total spin of the junction is 1/2. We perturbatively include a magnetic field, that allows us to change the spin state of the junction. The field gives rise to coherent Rabi oscillations between the equilibrium state and the state of opposite spin, where both bound states are occupied.

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Measurement of the electronic quantum shot noise at optical frequencies

When a voltage of few eV is applied between two metals separated by a thin oxide barrier, a tunnel current flows. This well-known electrical phenomenon is accompanied by an optical one: the generation of light. The emitted light, observed in the late 70’s by J. Lambe and S. L. McCarthy

[1], is broadband and can be viewed as the radiation due to the high frequency component of current fluctuations. In a tunnel junction, these fluctuations are related to the discrete nature of electrons, the so-called shot noise. In the quantum regime ($k_B T$ << hn), the power spectral density of the shot noise exhibits a high frequency cut-off determined by the applied voltage (*h*n ≤ *eV*). This regime is *readily* reached at optical frequencies n ~ 10^{14} Hz and nitrogen temperature T = 77 K. In this work, we report measurements of light emission from a tunnel junction and demonstrate unequivocally the relationship between non-symmetric emission shot noise and photon emission. From the measurement of nonlinear I-V characteristic, we precisely determine the energy/voltage dependence of electron *tunneling* transition probability T(e,eV) and verify that the measured photon emission rate at a given frequency is directly proportional to the theoretical prediction of the electronic shot noise at the same frequency.

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D. Feinberg, R. Mélin, A. Freyn, M. Fléser, D. Gosselin, G. Hornecker, A. H. Pfeffer, J. E. Duvauchelle, H. Courtois, F. Lefloch, J. Rech, T. Jonckheere, T. Martin, B. Douçot, C. Balseiro.

Transport in triterminal hybrid structures

Triterminal superconducting-normal metal structures will be briefly reviewed. They reveal new physical effects, owing to the existence of two control voltage or phase variables, for instance i) Cooper pair splitting in N-S-N structures [1], yielding nonlocal correlations between electrons; ii) Multipair transport in S-S-S structures, with the coexistence of DC and AC Josephson currents [2-5]; iii) Andreev spectroscopy in N-S-S or S-N-S structures [6]. The topic is mature for quantitative experiments [7], that extend the already rich field of hybrid structures and its potential applications in spectroscopy and quantum manipulation.

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Topology of driven crystals

Driven systems can exhibit peculiar topological properties which are not present in static systems. These properties are enhanced by symmetry constraints, as for their static counterpart.

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Stückelberg interferometry with a pair of Dirac cones in artificial graphene

Dirac cones are linear band contacts in crystals that are also characterized by a quantized Berry phase. The prime example of a crystal featuring a pair of Dirac cones is graphene (honeycomb lattice). Recently, artificial and tunable analogs of graphene were realized experimentally (e.g. with cold atoms). When deforming the honeycomb lattice, it is possible to manipulate the Dirac cones up to their merging and annihilation. The energy spectrum across the merging transition can be detected via Bloch oscillations and Landau-Zener tunneling as recently shown by Tarruell et al. This technique is not restricted to studying the energy spectrum and can give access to band coupling effects (Berry phases). The idea is to use a pair of Dirac cones to realize a Stückelberg interferometer. We will show that this type of interferometer contains information on band coupling in the form of an open-path (but gauge-invariant) Berry phase.

Mass and chirality inversion of a Dirac cone pair in Stückelberg interferometry, Lih-King Lim, Jean-Noël Fuchs, Gilles Montambaux, Phys. Rev. Lett. 112, 155302 (2014)

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Sebastian Toelle, Cosimo Gorini, Ulrich Eckern

Room temperature spin thermoelectrics in metallic films

Considering metallic films at room temperature, we present the first theoretical study of the spin Nernst and thermal Edelstein effects which takes into account dynamical spin-orbit coupling, i.e., direct spin-orbit coupling with the vibrating lattice (phonons) and impurities. This gives rise to two novel processes, namely a dynamical Elliott-Yafet spin relaxation and a dynamical side-jump mechanism. Both are the high-temperature counterparts of the well-known T=0 Elliott-Yafet and side-jump, central to the current understanding of the spin Hall, spin Nernst and Edelstein effects at low T. We consider the experimentally relevant regime T_D, with T_D the Debye temperature, as the latter is lower than room temperature in transition metals such as Pt, Au and Ta typically employed in spin injection/extraction experiments. We show that the interplay between intrinsic (Bychkov-Rashba type) and extrinsic (dynamical) spin-orbit coupling yields a nonlinear T-dependence of the spin Nernst and spin Hall conductivities.

preprint: arXiv:1409.1809 (2014)

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Correlations of microwave photons emitted by inelastic Cooper pair tunneling

A simple DC voltage-bias on a small Josephson junction leads to emission of microwave radiation via inelastic Cooper-pair tunneling. In this process a tunneling Cooper pair emits one or several microwave photons with a total energy of 2eV [1]. The observed average photon emission rate is well explained within the so-called P(E) theory [2], but this theory does not make any predictions about the statistics of the emitted photons. I will present experiments showing that these statistics can be highly nontrivial, in agreement with recent theory [3?5]. Depending on the bias conditions and the impedance of the circuit in which the junction is embedded, correlations can range from strongly bunched to anti-bunched. This type of devices might therefore offer a new way of generating useful photon states for circuit quantum optics experiments, without the need of carefully calibrated control pulses. Moreover, the frequency of the emitted radiation is only limited by the gap of the superconductor. We are building our devices using NbN-MgO-NbN tunnel junctions which should in principle allow operation up to the THz regime.

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Breathing modes of one-dimensional trapped BEC

Dynamic properties of one-dimensional ultracold bosonic gas are studied at zero temperature. Frequencies of low-lying excitations in a trap are calculated for the same parameters as in the recent experiment of the Innsbruck group [E. Haller et al., Phys. Rev. Lett. 104, 153203]. A variety of analytical approaches is used, including Bethe Ansatz, Gross-Pitaevskii and perturbative theories and is complemented with the quantum Monte Carlo simulations for N up to 25 particles. An expression for the frequency of the breathing mode is obtained, which successfully describes finite-size effects obtained in the experiment

[E. Haller et al., Phys. Rev. Lett. 104, 153203].

Sophie Guéron
Chuan Li, Katsuyoshi Komatsu, G. Clavé, S. Campidelli, A. Filoramo, S. Guéron and H. Bouchiat

Superconducting proximity effect through graphene grafted with Pt-porphyrins: detection of gate-tunable magnetism.

Inducing magnetism in graphene holds great promises, such as new exotic magnetic phases, or the control of exchange interaction via a gate electrode. To reach this goal, graphene has been coated with magnetic or rare earth atoms as well as molecular magnets, with mixed results. Adsorbed magnetic atoms reduced graphene's mobility, with no concurrent magnetic signature. In contrast, the magnetisation reversal of molecular magnets could be detected in a graphene

nanoconstriction. In the present work, we use Pt-porphyrins that interact with graphene's delocalised sp2 orbitals. Neutral Pt-porphyrins are non- magnetic, but the ionised form carries a magnetic moment of one Bohr magneton.
At room temperature we find that the molecules act as dopants, transferring charge to graphene and turning it neutral, with a Dirac point at zero gate voltage. In addition, the grafted graphene's mobility increases. At low temperature, we show how superconducting contact electrodes can uniquely reveal the magnetic order induced in mesoscopic graphene sheets. We find that this magnetism is controlled by gate voltage, with in some cases a suppressed supercurrent at positive gate voltage, and an enhanced supercurrent at negative gate voltage. These results may be a manifestation of the long sought-after Fermi-level controlled exchange interaction between localised spins and graphene.

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Density of states of interacting quantum wires with impurities: a Dyson equation approach
In one-dimensional systems, in which the interactions can be treated exactly using the Luttinger liquid theory and bosonization, it was shown that repulsive interactions like the Coulomb interactions renormalize the impurity strength, such that at low energy even a weak impurity has a very strong effect and can cut the wire into two pieces. This translates into a reduction of the local density of states (LDOS) at low energies, and the LDOS decays to zero as a power-law. At high energies the effect of the impurity consists in a small power-law correction of the unperturbed LDOS.
The two power-laws are characterized by two different exponents which depend on the interaction strength. On this poster, we present a new approach based on Dyson equation that allows to capture, by non-perturbative methods, the transition between the two regimes. This technique is applied to calculate the density of states for an interacting quantum wire in the presence of one then two impurities of arbitrary
potential strength.

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Kondo effect of an atom in contact with a multilayered tip
The Kondo effect is a many-body phenomenon which occurs when conduction electrons scatter on a magnetic impurity. Conduction electrons try to screen the spin of the impurity by forming a singlet state. Since spin flip processes are involved in this process, the Kondo effect is therefore very sensitive to the magnetic environment. Here we show that the Kondo effect can be used as an efficient probe of a spin polarized current at the atomic scale. We present scanning tunneling microscopy experimental results of the differential conductance measured with spin polarized tips in contact with magnetic atom adsorbed on a cooper surface. We show that the experimental results can be quantitatively described by the numerical renormalization group approach applied to the single impurity Anderson model connected to polarized electrodes.

Hugo Henck
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Electronic transport with Epitaxial Graphene and 2D-heterostructures

In literature, mobilities μ over 150000 cm2V-1s-1 at ambient have been measured recently with graphene nanoribbons epitaxially grown [Baringhaus], demonstrating the efficiency of this method and of graphene over typical materials. The LPN team has also a strong background in the epitaxial growth of large-area and monodomain graphene samples on insulating SiC with μ>10000 cm2V-1s-1 for 100μm devices. A prospective, in our lab., would be to integrate 2D heterostructures such as graphene growth on top of h-BN monolayer or, in a more exotic way, to laterally control the material nature. It will improve the transport efficiency and the 2D geometric control of the devices, for example to create a constriction as in quantum point contact. Physics of quantum Hall effect and transport measurements of these 2D electron gases will allow to measure diffusive or coherence lengths and to explore the mesoscopic aspect of such devices. LPN- Phynano group will input all its expertise in cryogenic low noise measurements and nanofabrication with top-gate electrodes, in order to create new optimized 2D heterostructures.

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Effect of a molecular grafting on electronic transport in epitaxial graphene

Being a two-dimensional material, graphene is very sensitive to surface effects such as molecular grafting. We will here present magnetotransport measurements of samples of epitaxial graphene, grown on silicon terminated face silicon carbide (Si-face of SiC), on which molecules are grafted by chemical processes. These measurements were carried with contacts made of a bilayer of titanium/aluminium following a 4-probe geometry and give us access to the density and mobility of charge carriers in graphene. The dependance of these two indicators were investigated according to the molecular grafting of two different species (diazonium polyoxometalate (POM) and cobalt phthalocyanine (CoPc)) and to the influence of their respective solvents. The measurements carried up to now seem to show that the solvent increases the electronic density and sample homogeneity without changing the mobility of electrons in graphene. The POM, while bonding in a covalent way with the carbon atoms of graphene, decreases the mobility with few changes to the electronic density. No consequent effects were found until now for the CoPc, probably due to the weak character of its van der Waals bonding with graphene.

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Magnon electrodynamics in Weyl semimetals

Weyl fermions, which are fermions with definite chiralities, can give rise to anomalous breaking of the symmetry of the physical system which they are a part of. In their (3+1) -dimensional realizations in condensed matter systems, i.e., the so-called Weyl semimetals, this anomaly gives rise to topological electromagnetic response of magnetic fluctuations, which takes the form of non-local interaction between magnetic fluctuations and electromagnetic fields. We study the physical consequences of this non-local interaction, including electric field assisted magnetization dynamics, an extra gapless magnon dispersion, and polariton behaviors that feature ``sibling" bands in small magnetic fields.

Reference: arXiv:1405.0491

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High frequency response of 3d topological insulators

We use different types of sources of bismuth selenide and -telluride ranging from mechanical exfoliation to molecular beam epitaxy in order to investigate electron transport in these three-dimensional topological insulators. We focus on capacitance measurementswhere access to broadband RF and microwave admittance spectra allow us to obtain information on the characteristic transport coefficients, e.g. electron compressibility and mobility. Using the different scattering times for surface and bulk carriers, we aim to separate the two contributions at high frequencies.

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Cooper pair splitting in a nano-SQUID geometry at high transparency

We propose a system made of two quantum dots coupled to two superconductors as a Cooper pair splitter. The achievements of high transparency junctions require to go beyond the traditional perturbative expansions which were sufficient to describe tunneling regimes. This is why we propose a non-perturbative treatment of this double Josephson junction. When a magnetic flux is introduced in-between the two quantum dots (SQUID geometry), we can probe the Cross Andreev process which is the delocalization of the two electrons of a Cooper pair, that travels from one superconductor to the other, on the two quantum dots. Then by adjusting the parameters of the quantum dots (0 or π phases), we can optimize this process. A splitting efficiency which can be computed whatever the transparency regime of the double Josephson junction is indeed defined.

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Parametric amplifier based on a voltage biased Josephson junction

Recently, microwave amplifiers based on superconducting circuits instead of semiconductors have reached noise levels very close to the quantum limit [1] but they are difficult to handle because of a severe gain-bandwidth trade-off and very small dynamic range [2]. Recent experiments with superconducting circuits consisting of a dc-voltage biased Josephson junction in series with a resonator, showed that a tunneling Cooper pair can emit two photons in different modes with a total energy of 2e times the applied voltage [3]. We show transmission measurements on the device in [3], indicating amplification. A theoretical analysis shows that this circuit can indeed

operate as Josephson parametric amplifier with high gain with the energy of a Cooper pair playing the role of the pump and the Josephson junction the role of linear medium. Interestingly, this amplifier has a different trade-off between gain and dynamic range : In existing JPAs the junction should be small to be as non-linear as possible, but large in order to handle large signals, whereas in our case, a larger junction size increases both gain and dynamic range. Therefore it might be easier to combine high gain, high bandwidth and high dynamic range.

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How to Detect The Inelastic Scattering of Photons Propagating in a Non-linear Electromagnetic Resonator

We Study the inelastic scattering of photons that propagate through a transmission line coupled with a superconducting circuit that forms a nonlinear element. Our motivation is predicting how the inelastic processes can be detected in the current-voltage characteristics(CVC) measured in a Josephson junction in series with the transmission line with the help of so called environmental P(E) theory [1]. In our work, the non-linear superconducting circuit is modeled as an oscillator with a weak an harmonicity. Our results predict a peak around $eV=\hbar w$ which is oscillator's resonant frequency in the CVC of the probing junction that is characteristic of the photon-photon interaction in the system.

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Photo-emf in a conductor tunnel coupled to 2D topological insulator

We study the edge states of 2D topological insulator being illuminated by circularly polarized light with frequencies higher than the difference between equilibrium Fermi level and the bottom of the conduction band resulting in electric dipole transitions between the edge states and the bulk states. We show that photo-emf is induced in a conductor tunnel-coupled to the illuminated 2D topological insulator.

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Nonlocal transport and heating in superconductor hybrid structures in the presence of a Zeeman field.

We theoretically investigate nonlocal spin transport properties of NISIN, FISIN, NISIF and FISIF hybrid structures. Significant interest to this field is connected with recent experiments on spin relaxation in superconductors detected by nonlocal transport measurements, for instance see Refs. [1-2]. The main idea is to apply bias voltage only in injector circuit and then to measure a current in detector circuit. Bias detector voltage is zero and hence nonzero detector current is only due to nonlocal effects. There is three possible causes of nonlocal effects in these hybrid structures: charge imbalance, spin imbalance and heating of superconductive wire induced by tunnel currents. First we consider only elastic processes and derive a diffusive kinetic equation in the superconductor in the presence of large Zeeman splitting. For systems with ferromagnetic detector it results in large detector current, which doesn't relax due to elastic processes in specific voltage interval. The larger magnetic field is the larger this interval is. It is this interval in which experimental signal has a maximum magnitude. Therefore inelastic energy relaxation processes like electron-electron and electron-phonon interactions are crucial. For the case of strong electron-electron interaction we show how tunnel currents lead to heating of superconductive wire and hence to nonlocal current. In the presence of large magnetic fields heat temperature Ts can be significant and even reach a critical temperature. Ts also demonstrates some interesting features as magnetic field dependent voltage threshold. We discuss relaxation of this heat-induced nonlocal current in dependence on Zeeman magnetic field, depairing parameter and distance to the leads. We propose a simple experimental way to manipulate a relaxation of nonlocal current.

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Minimal conductivity in semi-metallic phases

Semi-metallic phases are characterized by a crossing point of energy bands. We investigate the minimal conductivity at this crossing point for various 2D and 3D semi-metallic phases. Using analytical and numerical methods, we derive the dependance of the conductivity on the Fermi energy. In particular, we question the origin of the minimal conductivity in the seminal case of graphene, and study the effect of an additional flat band at the crossing point.

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Hong-Ou-Mandel experiment for temporal investigation of single electron fractionalization
Coulomb interaction has a striking effect on electronic propagation in one dimensional conductors. The interaction of an elementary excitation with neighboring conductors favors the emergence of collective modes which eventually leads to the destruction of the Landau quasiparticle. In this process, an injected electron tends to fractionalize [1,2] into separated pulses carrying a fraction of the electron charge. For example, in the integer quantum Hall regime at filling factor $\nu = 2$, an electron emitted and propagating in one edge channel (e.g the outer) is expected [3] to split in two fractional current pulses carrying charge e/2. In this paper, we follow the suggestion of Wahl [4] and collaborators and use two-particle interfer- ences in the electronic analog [5,6] of the Hong-Ou-Mandel [7] experiment to probe both the fate of a single Landau quasiparticle propagating in the outer edge channel and the collective excitations it generates in the inner edge channel. These complementary information reveal the fractionalization process in time domain and establish its relevance for the destruction of the quasiparticle which degrades into the collective modes.

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Single hole physics in Si and Si/Ge Nanowire Transistors: Towards Quantum Spintronics
Quantum spintronics aims at utilizing the quantum nature of individual spins to bring new functionalities into logic circuits. Owing to a limited hyperfine coupling, silicon-based nanostructures can allow for long spin coherence times, a key requirement for quantum spintronics [1]. Here we will present recent experimental progress on the confinement and control of individual holes in Si and SiGe devices fabricated with 300-mm CMOS technology. First we will present results for Si devices in which the few holes regime is accessible. The g-factor anisotropy study will be presented and possible implementation of spin manipulation via g-tensor modulation will be discussed. In a second part we will focus on an equally interesting physcis arising in a Single Atom Transistor (SAT) made in a SiGe device. Due to many-body Coulomb interaction a Fermi Edge Singularity [2] appears in the tunneling through the localized atom level. And for the first time we will experimentally explore such a FES depending on bias and gate voltages.

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Spatial structure at atomic scale of individual magnetic impurities in NbSe2 resolved by STS

The combination of superconductivity and magnetism has been known to give rise to localized states called Shiba states inside the superconducting gap [1]. These states are due to the breaking of a Cooper pair by the magnetic interaction. The amplitude of the measured peaks and the position of these peaks inside the gap depend on the specific parameters describing the interaction between the impurity and the conduction electrons. In addition to allowing the measurement of the spectrum associated with magnetic impurities through the localized density of states [2], scanning tunneling microscopy also enables us toaccess the spatial dependence of these particular states. Here we studied samples of superconducting NbSeé2 containing a really small concentration of native magnetic impurities. We observed the appearance of star-shaped structures around individual impurities with a size of the order of the coherence length of the superconductor (?10 nm). Though this type of structures where expected in this material under specific conditions [3], the fine study of our data revealed an oscillation of the density of states along the star branches. More specifically these oscillations were found to be phase shifted between electron and hole-like states. Theoretical calculations are ongoing at LPS using a tight binding approach, combining BCS coupling and magnetic interaction.

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Using a two-electron spin qubit to detect flying electrons

In quantum optic experiments with flying electrons, the flying electrons are so far detected via current measurement, summing up the contribution of millions of electron transfers between two contact pads and electron correlations are encrypted in the current noise. This represents an important limitation for the investigation of quantum correlations in experiments with flying electrons. To go beyond average measurements, it is necessary to detect an individual flying electron passing by a detector, a very difficult task to tackle with conventional detectors. However, quantum systems have been identified as extremely sensitive systems to external perturbations and potentially good detectors. Here, we investigate experimentally the coupling between a two-electron spin qubit defined in a AlGaAs-GaAs heterostructure and individual electrons propagating in the edge states of the Quantum Hall regime. We use two different ways to inject electrons into the edge state: either by a quantum point contact or a fast tunable quantum dot. We demonstrate that the qubit is an ultrasensitive and fast charge detector with the potential to allow single shot detection of a single flying electron. This work opens the route towards quantum electron optics at the single electron level above the Fermi sea.

arXiv preprint arXiv: 1403.7770

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Dynamical behavior of suspended carbon nanotubes close to the current blockade transition

We study the coherent quantum transport through a suspended carbon nanotube (CNT) in the quantum dot regime. We work in the Born-Oppenheimer approximation, when the typical frequency of the oscillator w0 is small compared to the two typical frequency scales of the electronic subsystem: (eV/ $\hbar$) and G (respectively, the voltage across the CNT and the width of the dot level); hence the oscillator can be treated classically. Neglecting fluctuations, we find a critical value for the electromechanical coupling at which the softening of the resonance frequency is maximum, and above which the oscillator becomes bistable and the current is progressively suppressed. To obtain information on the full dynamics of the system (with fluctuations), we derive its current- and displacement- noise spectra: we fully characterize the dependence of the resonant frequency as a function of the gate voltage, both in the stable and the bistable regime.

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Josephson coupling through a single nanowire: multi-periodic SQUID-like oscillations of the critical current

We theoretically show that the critical current of the Josephson junction consisting of two superconductors coupled through a nanowire with a small number of conductive channels can reveal multi-periodic oscillations as a function of the applied magnetic field. These oscillations originate from the quantum mechanical interference between the channels affected by both the strong spin-orbit coupling and Zeeman interaction. The suggested model may explain the complicated oscillatory behavior of the critical current, which was recently observed in Josephson transport through Bi nanowires [1].

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Phase shift of quantum oscillations as function of sample boundary conditions

The geometry and boundary conditions of a sample determine the phase shift of the measured Shubnikov de Haas oscillations (Berry Phase). Here we address some simple cases where this shift runs from -pi/2 to +pi/2 on a rectangular sample according to different width over length ratios and two equipotential edges at current contacts. Then we apply this concept in the interpretation of quantum oscillations of the organic compound a-(BEDT-TTF)2I3 where Dirac and massive fermions are present.

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Anomalous Josephson Effect in Junctions with Rashba Spin-Orbit Coupling

We study two-dimensional SINIS Josephson junctions in which the inversion symmetry in the normal part is broken by Rashba spin-orbit coupling. In the presence of a suitably oriented Zeeman field in the normal part, the system displays the anomalous Josephson effect: the current is nonzero even at zero phase difference between two superconductors. We investigate this effect by means of the Ginzburg-Landau formalism and microscopic Green's functions approach in the clean limit.

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Quasi-classical circuit theory of mesoscopic junctions with three superconducting terminals

Quasiclassical circuit theory [1] is used to investigate transport in a mesoscopic junction with three superconducting terminals. Apart from the Josephson effect, the junction exhibits non-local transport processes that correlate the superconducting currents flowing between different pairs of terminals. The properties and amplitude of the non-local processes are revealed and studied systematically in different biasing conditions. Our focus is on the lowest order non-local process, previously termed quartet [2], that involves the exchange of four quasiparticles between the three terminals. We show that the properties of junctions exhibiting quartets provide unique opportunities for applications in modern quantum devices based on Josephson and/or Majorana physics.

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Single Molecules coupled to nano-oscillators: strong coupling limit
We investigate how single molecule spectroscopy can be used to detect the displacement of a nearby nanomechanical resonator. We argue that a strong coupling to the moleculat electronic two-level system can be reached. Depending on the ratio of the mechanical frequency to the width of the optical transition different regimes exist that allow to detect the resonator frequency and its average amplitude in a browian motion. In the limit of slow oscillator we consider the strong coupling limit for which a static instability of the oscillator is predicted.

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Systematic electron-electron interaction corrections to nanoelectronics device properties
We develop a numerical technique for out of equilibrium interacting nanoelectronic systems. The technique calculates in a systematic way the development of observable quantities (such as current or density) in power of the electron-electron interaction coupling constant U - It corresponds to evaluating all the Feynman diagram to a given order Un. The technique belongs to the class of diagrammatic quantum Monte-Carlo and is based on the Keldysh Green's function formalism in real time. It relies on a sampling of the evolution operator which preserves unitarity by construction. We find that the computational cost to calculate the nth order contribution Un to a given observable scales exponentially as n22n, which is in practice rather mild. As a result, it works for a very large class of systems and moreover opens a wealth of new possibilities for calculating the properties of out of equilibrium, possibly time dependent, interacting nanoelectronic systems. We present examples of calculations up to U15 and discuss various schemes for extrapolating the series from moderate to strongly correlated regimes.

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Orbital Magnetism of Multiband Systems
Despite being an equilibrium property, orbital magnetism of multiband systems has been relatively little explored and many questions are still open. In this work, we investigate the orbital susceptibility of a multiband Hamiltonian and the consequence of interband coupling. We focus on two-band and three-band toy-models and we analyse the effect of different parameters in the magnetic response. In particular, identical spectrums can give rise to very different behaviors. Surprisingly, orbital magnetism can exist even if the chemical potential is in the gap.

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Heat current through inhomogeneous superconductors (e.g. presence of a domain wall)

Thermal transport in superconductors is widely used as an experimental probe of quasiparticle states, and of the gap structure. Although thermal conductivity of uniform superconductors have been studied a lot, much less is known about the details of thermal transport through a spatially-dependent order parameter. Such situations arise, for example, in vortex states. In particular, the heat transport may be strongly affected by the presence of Andreev bound states (e.g. pinhole set-up) and/or by space varying thermal equilibration and quasiparticle scattering time (due to an inhomogeneous density of states). In this work, we investigate the heat transport in the presence of a single domain wall, where the amplitude of the order parameter changes on the scale of the coherence length from +Δ on the left of x axis to -Δ on the right. Such domain walls may arise due to boundary conditions or in a speculative Fulde-Ferrell-Larkin-Ovchinnikov state. In linear response, for both s-waves and d-waves, we study the thermal current across or along the domain wall. For transport across the domain wall, we find that the temperature gradients needed to sustain a uniform heat current density, are strongly non-monotonous around the domain wall, and may even switch direction (negative). Hence, the heat current response at the domain wall is strongly non-local, reflecting large changes in the quasiparticle scattering times in its vicinity.

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Stress induced excitations in a spin glass

Glassy systems are one of the most fascinating and complex state of matter. Their theoretical description can be useful to the study of a wide variety of phenomena ranging from sociology to biology or even financial markets. It is also a perfect example of disordered and frustrated system, which leads to non-trivial ground-state with original and subtle topological properties. In our work, we show that the system can be pushed out-of equilibrium using a very tiny variation of an external parameter, just like magnetic field: we thus have the possibility to drive and control the system out of equilibrium.

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Silicon artificial atoms with large charging energies based on a scalable deep-UV lithography process

Electrons behave differently within the channel of a transistor ? even in a nanoscopic one -, than in atoms where isolation from environment and charging effects set the number of electrons. In a conventional MOSFET transistor, the source-drain electrodes are usually far too intrusive to achieve atomic-like transport characteristics. There is indeed no quantization of the motion along the source-drain direction due to the short lifetime of carriers within the channel. Nevertheless, the gap between real and solid state artificial atoms is narrowing quickly. This fosters a genuine interest for circuit functionalities mimicking atomic behavior, such as quantum bits or tunnel devices where carrier orbitals are tailored by an electric field. For useful applications, artificial atoms should be scalable and possibly integrable on standard CMOS circuits. We report the observation of an atomic like behavior from T=4.2 K up to room temperature, in devices made on 300mm wafers in a CMOS foundry using state-of-the-art deep UV (DUV) lithography. For that purpose, long offset spacers were introduced in the standard process flow of a nanowire transistor, in order to achieve non invasive source and drain. The channel was also made extremely small (3.4 nm in diameter with 10 nm gate length), and the gate oxide thick (7 nm), in order to enhance the Coulomb repulsion between carriers, which exceeds by much the thermal energy at room temperature.

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Flat bands of Majoranas in 2d - topology and stability

Majorana bound states have been shown to exist in both one dimensional and two dimensional superconductor models in the presence of Rashba spin-orbit coupling and appropriate magnetic fields. In this paper we show that for a range of inhomogeneous magnetic fields it is possible to create flat bands of Majorana states localized on the edges of 2-d lattices. For such systems we present the bulk topological phase diagrams, and the weak topology which predicts bands of Majorana states. The Majorana bands are demonstrated to be relatively stable with respect to a variety of different perturbations on both square and hexagonal lattices.

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Transmission Phase Shift across a Quantum Dot with Strong and Weak Kondo Correlations

We have recently studied the transmission phase shift of an electron across a Kondo correlated quantum dot at temperatures around the Kondo temperature T_K and well above. Using an original two-path interferometer [1] we have been able to make unambiguous phase shift measurement in the Kondo regime and found excellent agreement with theory [2]. In the present work, we focus on the phase behavior in the low temperature regime ($T<<T_K$). We find that the phase smoothly evolves by pi across two Coulomb peaks without showing a plateau at pi/2 at T_K and starts being locked around pi/2, only when T is increased and gets closer to T_K. Such a phase evolution allows for precise evaluation of T_K and gives information about the Kondo density of state. We also investigate the phase evolution at T_K, where the asymmetric phase evolution with respect to pi/2 at the valley center was observed [2]. According to NRG calculations, such an asymmetry is determined by the orbital parity relation between nearby quantized levels, which leads to the appearance of an abrupt phase lapse in the valley between two different orbitals through the generalized Friedel's sum rule. We indeed confirm experimentally this relation between the asymmetries and the phase lapse as well as the orbital parity relation.

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Scattering theory of topological phases in discrete-time quantum walks

One-dimensional discrete-time quantum walks show a rich spectrum of topological phases that have so far been exclusively analysed based on the Floquet operator in momentum space. In this work we introduce an alternative approach to topology which is based on the scattering matrix of a quantum walk, adapting concepts from time-independent systems. For quantum walks with gaps in the quasienergy spectrum at 0 and , we nd three dierent types of topological invariants, which apply dependent on the symmetries of the system. These determine the number of protected boundary states at an interface between two quantum walk regions. Unbalanced quantum walks on the other hand are characterised by the number of perfectly transmitting unidirectional modes they support, which is equal to their non-trivial quasienergy winding. Our classication provides a unied framework that includes all known types of topology in one dimensional discrete-time quantum walks and is very well suited for the analysis of finite size and disorder effects. We provide a simple scheme to directly measure the topological invariants in an optical quantum walk experiment.

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Two-particle electronic coherence in quantum Hall channels

We investigate the two-electron coherence in QH channels. In particular, we focus on - a physically relevant definition of the two-particle coherence emitted by a source - its basic properties, in particular wrt the symmetries - various representations and their interest - the relation with the current noise - a setup able to measure it - some setups able to generate it from single electron sources

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Non-classical light emitted by a voltage-biased Josephson junction coupled to two resonators

We investigate the properties of the light emitted by a voltage-biased Josephson junction coupled to two superconducting oscillators with non-identical frequencies. We derive an effective Hamiltonian describing the interaction between the JJ and the oscillators, and show that depending on the particular implementations, the resulting photons can show pronounced non-classical behavior that is quantified by the second-order photonic correlation function $g_2(\tau)$. Specifically, when the bias voltage equals the sum of the frequencies of the two oscillators, the emission of the photons in the two cavities is strongly correlated, resulting in exotic states of light such as, for example, the squeezed states.

We calculate explicitly the $g_2(\tau)$ function in different limits, and show that the non-linearities in the electronic of the Cooper-pairs tunneling results in either photon bunching or anti-bunching that reveal the statistics the emitted light and the corresponding correlations.

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Aharonov-Bohm oscillations in quantum wire of 3D-topological insulator

Studying Aharonov-Bohm (AB) effect in a nanowire of topological insulator is a convenient way to reveal the specific properties of the topological surface states (SS), which are spin-chiral Dirac fermions. In the short perimeter limit, we evidenced in a previous work the ballistic transport of the SS in the perimeter of the nanowire, revealed by the temperature dependance of the phase coherence length [1] and showing the weak scattering effect of disorder on Dirac fermions. The quantum transverse confinement of SS is further revealed by the observation of non-universal conductance fluctuations. In the longer perimeter limit, we surprisingly find that the transport remains ballistic in the perimeter, despite the presence of disorder. The interaction with disorder is revealed by specific phase-jump of the AB oscillations under transverse magnetic field.

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Large current noise in nanoelectromechanical systems close to continuous mechanical instabilities

We investigate the current noise of nanoelectromechanical systems close to a continuous mechanical instability. In the vicinity of the latter, the vibrational frequency of the nanomechanical system vanishes, rendering the system very sensitive to charge fluctuations and, hence, resulting in very large (super-Poissonian) current noise. Specifically, we consider a suspended single-electron transistor close to the Euler buckling instability [1,2,3]. We show that such a system exhibits an exponential enhancement of the current noise when approaching the Euler instability which we explain in terms of telegraph noise [4].

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Transmission phase of a quantum dot and statistical fluctuations of partial-width amplitudes

Experimentally, the phase of the amplitude for electron transmission through a quantum dot (transmission phase) shows the same pattern between consecutive resonances. Such universal behavior, found for long sequences of resonances, is caused by correlations of the signs of the partial-width amplitudes of the resonances. We investigate the stability of these correlations in terms of a statistical model. For a classically chaotic dot, the resonance eigen functions are assumed to be Gaussian distributed. Under this hypothesis, statistical fluctuations are found to reduce the tendency towards universal phase evolution. Long sequences of resonances with universal behavior only persist in the semiclassical limit of very large electron numbers in the dot and for specific energy intervals. Numerical calculations qualitatively agree with the statistical model but quantitatively are closer to universality

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Josephson junction embedded in a resonator: from Coulomb blockade to parametric resonance

We present preliminary measurements of the time resolved g2 function of the photons emitted by a dc biased Josephson junction embedded in a microwave resonator: the quantum fluctuations of the current through the junction couples to the resonator, so that a dc current flows through the junction when the transfer of a Cooper pair corresponds to the emission of an integer number of photons into the resonator. These photons can then retroact on the transfer of other Cooper pairs via stimulated emission or absorption of photons by the junction. In the specific case of two-photon emission, retroaction has been recently predicted to result in a superbunching of the emitted photons. This is characterized by a divergence of the Fano factor at a threshold value for the junction's critical current [Padurariu, Hassler and Nazarov, Phys. Rev. B, (86), 054514 (2012)], which corresponds to the classical onset for parametric amplification of the resonator by the ac Josephson current.
We probe this prediction by dc biasing a SQUID through a quarter-wavelength microwave resonator and measuring the fluctuations of the emitted photon flux in an Hanburry-Brown-Twiss set up. By varying the flux through the SQUID, we can tune its effective Josephson energy to approach the predicted onset. Our results do show an increase of the Fano factor with increasing critical current.

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Manipulating Andreev and Majorana Bound States with radio-frequency
The Andreev bound states that form at the boundary of a superconductor are receiving renewed attention for topologically non-trivial materials where they are known as Majorana states; promising candidates as Quantum bits for topologically protected quantum computation. The simplest, yet somehow ambiguous, experimental signature for these Majoranas is the presence of a zero bias peak in the differential conductance. Here we show that adding microwave radiation to the measuring electrodes allows one to manipulate the Andreev/Majorana bound states, providing unambiguous signatures for their presence as well as their full characterization.

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Most efficient quantum thermoelectric at finite power output
Machines are only Carnot efficient if they are reversible, but then their power output is vanishingly small. Here we ask, what is the maximum efficiency of an irreversible device with finite power output? It turns out that classical thermodynamics is insufficient to answer this rather simple question; we need quantum mechanics. We apply a nonlinear scattering theory to thermoelectric quantum systems; heat engines or refrigerators consisting of nanostructures or molecules that exhibit a Peltier effect. We find that quantum mechanics places an upper bound on both power output, and on the efficiency at any finite power. The upper bound on efficiency equals Carnot efficiency at zero power output, but decays with increasing power output. It is intrinsically quantum (wavelength dependent), unlike Carnot efficiency. This maximum efficiency occurs when the system lets through all particles in a certain energy window, but none at other energies. A physical implementation of this will be discussed, as will the suppression of efficiency by a phonon heat flow.

Phys. Rev. Lett. 112, 130601 (2014) and arXiv:1408.3348

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A gate-tunable contact junction in graphene
Many applications of graphene rely on the high tunability of its electronic properties. Actually one remaining challenge is the possibility of gating the graphene contacts themselves; this issue is especially important for high-frequency electronics to minimize the contact resistance that dominates in short channel transistors. In this work we directly control the contact resistance of a graphene transistor using a device with independent channel and contact local back gates. We demonstrate a full control of contact doping by inverting the polarity of the contact. Besides, this geometry allows to realize ballistic junctions at the contact edge and/or within the channel.

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Transport vs local properties of mesoscopic graphene devices

We study the properties of mesoscopic graphene devices by combining in situ transport, AFM and STM measurements at milliKelvin temperatures. This allows cross-correlating the macroscopic properties seen in transport (charge neutrality point, mobility...) with local properties that can only be resolved by scanning probe microscopy (e-h puddles distribution, doping at graphene-lead interface, screening at the graphene edges, ...). Using AFM, we study how the back gate potential applied to the device is screened by the graphene, as a function of device thickness, gate potential and distance to the graphene edges. Using STM we map the local density of states on the same samples, revealing variations of the local charge neutrality point, in particular near the contacts. Besides zero bias anomalies in the tunnel spectra - indicative of charging effects in the graphene - we further report striking fringes in the LDOS of few layer devices that can be understood in terms of incommensurate stacking-induced strain.

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