GDR 2426

Physique Quantique Mésoscopique

Aussois, 15 - 18 octobre 2012

ORGANISATEURS

Les responsables de la session

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- **Marie-France Mariotto**

Lundi 15 octobre 2012

Session 1 : Boîtes quantiques

14h – 15h	E. Laird	*A valley-spin qubit in a carbon nanotube*
15h – 15h30	P. Petit	*Universal scaling of the two-stage Kondo effect in carbon nanotube quantum dots*
15h30 – 16h	R. Whitney	*Nonlinear thermoelectricity in point-contacts at pitch-off: a catastrophe aids cooling*

Session 2 : Hybrides

16h – 16h30	D. Feinberg	*Quartet and multi-pair correlations in a Josephson bijunction*
16h30 – 17h Pause		
17h – 17h30	A. Pfeffer	*Transport properties of three-terminal hybrid superconductor – normal metal nanostructures*
17h30 – 18h	C. Girit	*Detecting excited Andreev bound states in a one-atom contact*
18h – 18h30	E. Lee	*Andreev bound states spectroscopy in InAs nanowire quantum dots*
18h30 – 19h	M. Ferrier	*Probing the Dynamics of Andreev States in Coherent Normal/Superconducting ring*
19h45 Repas		

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Session 3 : Atomes froids

8h30 – 9h30	S. Nascimbene	*Artificial gauge fields with ultracold atomic gases*
9h30 – 10h	J.-P. Brantut	*Conduction properties of ultracold Fermions*
10h – 10h30 Pause		
10h30 – 11h	Ch. Grenier	*Thermoelectric transport of ultracold fermionic atoms*
11h – 11h30	L. Tarruell	*Engineering Dirac points with ultracold fermions in optical lattices*
11h30 – 12h	L. K. Lim	*Bloch-Zener Oscillations across a Merging Transition of Dirac Points*
12h15	Repas	
16h30 – 17h	V. Josse	*Ultracold atoms in disorder: 3D localization and coherent backscattering*

Session 4 : Nanomécanique

17h – 17h30	S. Seidelin	*A single nitrogen-vacancy defect coupled to a nano-mechanical oscillator*
17h30 – 18h	M. Ganzhorn	*Dynamics and dissipation induced by single-electron tunneling in carbon nanotube nanoelectromechanical systems*
18h – 18h30	Pause	
18h30 – 19h	J. Chaste	*Ultrasensibility of nanoresonators : Carbon NEMS*
19h – 19h30	V. Bouchiat	*A local optical probe for measuring motion and stress in a nano-electro-mechanical system*
19h45	Repas	
20h30 - …		Session affiches

Mercredi 17 Octobre 2012

Session 5 : Matière topologique et Graphene

8h30 – 9h	J. Cayssol	*Various probes of topological matter*
9h – 9h30	O. Crauste	*Band structure on strained HgTe topological insulator*
9h30 – 10h	S. H. Jhang	*Hot electron cooling in graphene*
10h – 10h30	Pause	
10h30 – 11h	J. Renard	*Low temperature dephasing in graphene*
11h – 11h30	I. Petkovic	*Edge magneto-plasmons in graphene*
11h30 – 12h	G. Usaj	*The electronic structure of F and H on graphene and their effect on graphene's transport properties*
12h15	Repas	

Session 6 : Spintronique

16h30 – 17h30	M. Chshiev	*Theoretical aspects of spintronic phenomena in magnetic tunnel junctions and graphene based structures*
17h30 – 18h	V. Cros	*Non linear magnetization dynamics driven by the interaction between spin current* and magnetic moments
18h – 18h30	Pause	
18h30 – 19h	L. Limot	*Spin injection and detection with a single Kondo atom*
19h – 19h30		Discussion GDR
19h45	Repas	
20h30 - …		Session affiches

Jeudi 18 Octobre 2012

Session 7 : Transport quantique

9h – 9h30	H. Sellier	*Transport mésoscopique dans un réseau semiconducteur étudié par microscopie à grille locale*
9h30 – 10h	C. Bena	*Mutation of Andreev bound states into Majorana states in long NS and SNS junctions*
10h – 10h30	Pause	
10h30 – 11h	C. Bauerle	*Transmission phase in the Kondo regime revealed in a true two-path interferometer*
11h – 11h30	D. Weinmann	*Transmission phase in quantum transport: effects of disorder, chaos and electronic correlations*
11h30 – 12h	X. Jehl	*A two-atom electron pump*
12h15	Repas	

Session 8 : Transport quantique micro-ondes

15h30 – 16h	F. Portier	*Dynamical Coulomb blockade of the high frequency noise of a tunnel junction*
16h – 16h30	F. Mallet	*Stabilizing the trajectory of a superconducting qubit with projective quantum feedback*
16h30 – 17h	E. Flurin	*The Josephson mixer, a swiss army knife for microwave quantum optics*
17h – 17h30	E. Bocquillon	*Single electron experiments in a quantum Hall device*

Affiches

R. Avriller	Quantum transport and electromechanical properties of Josephson junctions made of carbon nanotube quantum dots
D. Badiane	Non-equilibrium josephson effect through helical edge states
B. Brun	Scattering gate Interferometry at a quantum point contact
D. Chevallier	Mutation of Andreev into Majorana bound states in long NS and SNS junctions
F. Couëdo	Superconductor-Insulator Transition in amorphous NbSi thin films
B. Delsol	Epitaxie de couches minces supraconductrices de rhénium sur saphir
P. Devillard	Electron injection with Coulomb interactions
E. Dumur	Couplage entre un atome artificiel à effet Kerr et une cavité micro-onde
E. Dupont-Ferrier	Centre NV unique couplé à un oscillateur nano-mécanique
I. Ferrier-Barbut	Gaz de Bose unitaire, pertes à trois corps.
G. Forestier	Quantum transport in spin glasses
V. Freulon	Direct observation of neutral and charge modes in one-dimensional chiral edge channels
B. Gaury	Time resolved simulations for quantum transport
M. Guigou	Spin-dependent thermoelectric transport in HgTe/CdTe quantum wells
M. Hofheinz	Devices for microwave quantum optics based on single Cooper pair tunneling
L. Jansen	Gate-tunable localization effects in superconducting graphene junctions.
T. Jonckheere	Electron and hole Hong-Ou-Mandel interferometry
T. Jullien	Implementation and test of a Levitov n-electron coherent source
A. Kleshchonok	2D electron interferometer: □ interaction and temperature effects
F. Konschelle	Decoherence of the Majorana fermions
C. Li	Superconducting proximity effect through long S/graphene/S junctions from zero field to the quantum Hall regime
L. Longchamgbon	BEC in a highly anisotropic dressed quadrupole trap
C. Mora	Réponse dynamique d'un nanoconducteur : l'exemple du circuit RC quantique
A. Mostovov	A 4-point cross-correlation voltage noise set-up for investigating the shot noise of ballistic graphene nano-constrictions
E. Orignac	Magnetic impurity on the surface of a strong topological insulator
O. Parlavecchio	Implementation of a Tunable High-Impedance Microwave Environnement
C. Petitjean	Superconducting order and spin-orbit competition on graphene
V. Puller	Single molecule detection of nanomechanical motion
C. Richard	Andreev current induced by ferromagnetic resonance
P. Roulleau	On-chip photon-assisted detection of the noise of a quantum point contact
S. Samaddar	Superconducting nanostructures with thermally evaporated Niobium
R.-J. Tarento	Ecrantage dynamique lors de la formation d'une lacune dans un ruban de graphène : effet du spin-orbite
C. Tonnoir	Tunneling spectroscopy study of graphene on superconducting Rhenium
B. Voisin	Correlation and interaction effect between few electrons in a doped silicon nanowire
C. Wahl	Effect of Coulomb interaction on two electron interferences in the nu=2 quantum Hall effect
G. Weick	Giant current noise in nano-electro-mechanical systems close to mechanical instabilities
G. Weick	Massless Dirac bosons in honeycomb plasmonic lattices

Lundi 15 Octobre 2012

Session 1 : Boîtes quantiques

A valley-spin qubit in a carbon nanotube

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Carbon nanotubes are attractive materials for electron spin qubits because they can be made free of hyperfine dephasing and because spin-orbit interaction offers a route to all-electrical spin control. However, the existence of the valley degree of freedom and unscreened Coulomb interaction make the qubit readout complicated. Using a new fabrication technique, we have demonstrated combined valley-spin Pauli blockade in a nanotube double quantum dot by exploiting the bandgap to increase the energy splitting between blocked and unblocked states. This effect provides a readout mechanism for a qubit based on two valley-spin states of an electron. Making use of spin-orbit coupling in a bent nanotube, we drive coherent rotations between the qubit states, and demonstrate universal qubit control. The coherence time is found to be 65 ns, surprisingly short given the low density of nuclear spins.

Universal scaling of the two-stage Kondo effect in carbon nanotube quantum dots

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In quantum dots occupied by a fixed number of electrons, the Kondo screening of a single unpaired spin acting as an impurity results in a conductance peak at low bias completely determined the Kondo temperature. However, when the single-channel Kondo effect is in competition with intradot ferromagnetic coupling in the regime of even parity in the dot, the exact opposite behaviour is expected [1]. A fingerprint of this so-called two-stage Kondo effect is a dip in the conductance peak whose width is described by a second temperature scale T* [2].
We have investigated the two-stage Kondo effect in ultrasmall carbon nanotubes quantum dots fabricated by electromigration. We report on a pronounced dip within the Kondo peak observed at zero magnetic field. The temperature dependence of the conductance exhibits two characteristic energies. We ascribe this behavior to a two-stage Kondo effect occuring in the spin-singlet ground state of the quantum dot. We show that the temperature and voltage dependence of the dip in the Kondo resonance are consistent with the universal scaling function [3] of the spin ½ Kondo effect.

[1] W. Hofstetter and H. Schoeller, Phys. Rev. Lett. 88, 016803 (2002)
[2] N. Roch, S. Florens, V. Bouchiat, W. Wernsdorfer, and F. Balestro, Nature 453, 633 (2008).
[3] M. Grobis et al., Phys. Rev. Lett. **100**, 246601 (2008).

Nonlinear thermoelectricity in point-contacts at pitch-off: a catastrophe aids cooling

Robert S. Whitney
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Theoretical interest in mesoscopic devices which exhibit thermoelectric effects, has been recently rekindled by experiments showing mesoscopic thermoelectric refrigerators.The textbook theory of thermo-electric refrigerators uses linear-response theory to gives the quality of thermoelectric devices in terms of a "figure of merit". However, a good refrigerator rarely operates in the linear-response regime; if it cools to temperatures much below the ambient temperature, then the temperature difference is not a small parameter. As a result, we need to study the nonlinear thermoelectric response of mesoscopic devices.
Taking the nonlinear thermoelectric response of point-contacts, I show that a refrigerator can be much better than the linear-response "figure of merit" indicates. The lowest achievable temperature has a discontinuity at a critical driving current of the type called a "catastrophe" in mathematics. This catastrophe greatly aids cooling; currents above the critical current should allow one to (in principle) cool all the way to absolute zero (much colder than implied by the figure of merit). To conclude, we show that phonons and photons stop cooling at a temperature above absolute zero (as expected), and can also modify the nature of the catastrophe.

Preprint - arXiv:1208.6130 (submitted to Phys. Rev. Lett.)

Lundi 15 Octobre 2012

Session 2 : Hybrides

Quartet and multi-pair correlations in a Josephson bijunction

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A Josephson.bijunction connects three superconductors in a region of size comparable to the coherence length. Then, due to nonlocal Andreev and cotunneling processes, three-terminal transport opens the possiblility of correlated pairs (quartets, sextets..) crossing the two adjacent junctions. This induces a microscopic coupling between their respective phases. A striking consequence is the possibility of a phase-coherent and resonant dc transport of correlated pairs even though two of the superconductors are set at nonzero voltages, provided they satisfy a commensurability relationship $nV_1 + mV_2 = 0$. This is suggested by an adiabatic (low-voltage) argument, and confirmed by a fully nonequilibrium Keldysh calculation. In the case where the junctions are made with a single level quantum dot, an enhancement by three orders of magnitude of the quartet critical current is obtained with respect to the adiabatic limit, when the dot levels are resonant with the voltages $V_1 = - V_2$. Some prospects will be presented in terms of quantum entanglement and of production of correlated microwave photons.

[1] Axel Freyn, Benoît Douçot, Denis Feinberg, and Régis Mélin, « Production of Nonlocal Quartets and Phase-sensitive Entanglement in a Superconducting Beam Splitter », Phys. Rev. Lett. 106, 257005 (2011).
[2] Régis Mélin, Thibaut Jonckheere, Jérome Rech, Thierry Martin, Benoît Douçot, and Denis Feinberg « Multipair Dc-Josephson Resonances in a Biased All-Superconducting Bijunction », submitted.

Transport properties of three-terminal hybrid superconductor –normal metal nanostructures

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We present measurements of conductance in three-terminal Superconductor-Normal metal-Superconductor (S_a-N-S-N-S_b) nanostructures that are potential solid-state entanglers thanks to Andreev reflections at the N-S interfaces. Our results have been obtained using a unique SQUID-based experimental set-up working at very low temperature (30 mK) and dedicated to high sensitive conductance and crossed correlation measurements 3-terminal nanodevices [1]. The sample design consists of a central superconducting electrode S (aluminum), which is connected to two other superconductors S_a and S_b through a T-shaped normal metal part (copper). For a distance d_s of the superconducting reservoirs in the order of the coherence length ξ_s, new subgap anomalies appear by tuning the potential of the superconductors S_a and S_b. The two-dimensional conductance plot reveals new lines of sub-gap anomalies that are consistent with MAR processes including all three superconducting reservoirs [2]. The possibility that these new features are signatures of “quartets” (phase coherent pairs of Copper pairs) is discussed [2,3,4].

[1] B. Kaviraj, O. Coupiac, H. Courtois and F. Lefloch, *Noise and correlations in three terminal superconductor – normal metal – superconductor nanostructures*, Phys. Rev. Lett. 107, 077005 (2011)
[2] J. C. Cuevas and H. Pothier, *Voltage induced Shapiro steps in a superconducting multiterminal structure*, Physical Review B 75, 174513 (2007)
[3] M. Houzet and P. Samuelsson*, Multiple Andreev reflections in hybrid multiterminal junctions*, Phys. Rev. B 82, 060517 (2010)
[4] A. Freyn, B. Douçot, D. Feinberg, and R. Mélin, *Production of Nonlocal Quartets and Phase-Sensitive Entanglement in a Superconducting Beam Splitter*, Phys. Rev. Lett. 106, 257005 (2011)

Detecting Excited Andreev Bound States in a One-Atom Contact

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An abrupt variation of the superconducting phase--such as at a superconducting tunnel junction or microbridge--results in the creation of Andreev bound states. These states come in pairs with the ground level giving rise to the conventional Josephson current. Here we detect the transition to the *excited* Andreev bound state in a superconducting atomic contact using a Josephson junction as a broadband (5-100 GHz) spectrometer. Not only do we clearly resolve the Andreev transition, but we also identify spectroscopic lines arising from anticrossings with electromagnetic modes of the environment.

Lundi 15 Octobre 2012

Session 2 : Hybrides

Andreev-bound state spectroiscopy in InAs nanowire quantum dots

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3 Materials Science Insitute of Madrid, Madrid, Spain

In hybrid devices which couple superconducting electrical leads to low-dimensional semiconductors, electron transport within the superconducting gap (Δ) is governed by Andreev processes. This occurs as a consequence of the absence of quasiparticle states at the Fermi level. In fact, supercurrents are transmitted through quantum dots (QDs) by discrete states called Andreev Bound States (ABS). The experimental observation of ABS in quantum dot devices has been recently achieved by means of tunnelling spectroscopy measurements [1-3]. Here, we present a systematic study of the evolution of ABS in QD devices as the tunnel coupling to the leads was tuned by the back gate voltage. Our devices are comprised of QDs based on core/shell InAs/InP nanowires coupled to a normal metal (Au) and a superconductor (Al). We observed that for odd occupations, the ABS is strongly affected by altering the tunnel coupling. These observations reveal a transition from a magnetic doublet ground state to a singlet state upon increasing the coupling.

[1] R. S. Deacon et al., PRL 104, 076805 (2010)
[2] J.-D. Pillet et al., Nature Phys. 6, 965 (2010)
[3] T. Dirks et al., Nature Phys. 7, 386 (2011)

Probing the Dynamics of Andreev States in Coherent Normal/Superconducting ring

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A dissipationless current is known to flow through a thin (subnanometer) insulating barrier between two superconductors S with a superconducting phase difference, the well-known Josephson effect.
This supercurrent may also flow through a long (micrometer) non-superconducting metal wire at low temperatures, a spectacular consequence of the quantum phase coherence throughout the normal metal. The way the supercurrent responds to a dc phase difference, the current-phase
relation, was only recently measured with a Hall probe[1]. It reflects the phase dependence of the Andreev bound states (ABS) , entangled electron-hole states which form in the normal metal as a consequence of the superconducting mirror-like boundary conditions. However little is known about the dynamics of these ABS and their relaxation.
In order to investigate the evolution of the current phase relation in such superconductor/normal metal/superconductor (SNS) junctions with high frequency phase driving, we have inductively coupled one NS ring to a multimode superconducting resonator[2]. The in-phase (□') and out-ofphase (□'') ac magnetic susceptibility of the ring is deduced from the dc flux dependence of the resonance frequency and quality factor of the resonances from 300 MHz up to 6 GHz. Our results show that the frequency dependence of the susceptibility is governed by two different dynamical processes. These two contributions can be separated by their different flux dependence.
One is the inelastic relaxation time responsible for the thermalization. Depending on the sample investigated, it corresponds to an inelastic rate lower or of the order of the lowest frequencies of our set up. As a consequence, populations are frozen giving a large harmonic contents in the current/phase relation. The second process involves transitions above the minigap and is dominant at high frequencies. It is responsible for a strong □'' contribution and the frequency dependence of the susceptibility. These results are compared to recent theoretical findings and stimulate future similar investigations on more exotic junctions. This experiment also illustrates a new tool to probe the fundamental time scales of phase coherent systems that are decoupled from macroscopic normal contacts and thermal baths.

[1] M. Fuechsle et al., Phys. Rev. Lett., **102**, 127001 (2009)
[2] F. Chiodi et al., Nature Scientific Reports **1**, 3 (2011)

Mardi 16 Octobre 2012

Session 3 : Atomes froids

Artificial gauge fields with ultracold atomic gases

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Ultracold atomic gases constitute a remarquably flexible playground for the study of quantum many-body systems. In the recent years the development of experimental techniques such as optical lattices or Feshbach resonances led to the realization of model strongly-interacting systems such as Mott insulators, low-dimensional systems or Fermi gases in the BEC-BCS crossover. One of the main missing ingredient appears to be orbital magnetism, that would allow one to explore quantum-Hall physics and beyond with atomic gases. We will review the main techniques that were recently developped, such as rotating atomic gases, laser-induced geometrical phases or gauge potentials in optical lattices. We will present the main characteristics of quantum Hall systems and topological matter that could be realized with atomic gases in the future, as well as the relevant probes specific to atomic physics.

Conduction properties of ultracold Fermions

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We experimentally study the conduction properties of ultracold fermionic atoms ?owing through a quasi two-dimensional channel connecting macroscopic, incoherent reservoirs. An atomic current is induced by creating an imbalance in the particle number of the two reservoirs.
Combining the measurement of the current with the high-resolution measurement of the density in the channel, we observe the drop of chemical potential due to the contact resistance which develops at the contacts between the ballistic channel and the reservoirs. Analogous to a ?eld-effect transistor, we use an additional beam to independently tune the atomic density in the channel region and study the current as a function of the chemical potential. For a strongly interacting Fermi gas we observe a striking increase of the current characteristic of the onset of super?uidity. Prospects for the investigation of the interplay between strong interactions and disorder are discussed.

Thermoelectric transport of ultracold fermionic atoms

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We make a proposal for revealing thermoelectric effects in the transport properties of ultracold fermionic atom, using the setup recently realized in the ETH group [1]. This setup consists in two reservoirs connected by a conducting channel. We present a theoretical analysis of the expected effects, and emphasize that an intrinsic thermoelectric effect due to the finite dilatation coefficient of the gas in the reservoirs arises in the context of atomic gases. This effect combines with the thermoelectric properties of the conduction channel to give rise to the total off-diagonal transport properties of the system. We propose an experimental protocol which directly probes the thermoelectric response and off-diagonal transport coefficients. The expected magnitude of the effects should make it possible to observe them in currently available experimental setups.

[1] J.-P. Brantut, *et al.*, arxiv :1203.1927v2HYPERLINK "http://arxiv.org/abs/1203.1927v2" 1203.1927v2 , accepted for publication in Science
[2] Ch. Grenier, C. Kollath & A. Georges, « Thermal and thermoelectric transport of ultracold fermions », in preparation

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Mardi 16 Octobre 2012

Engineering Dirac points with ultracold fermions in optical lattices

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Laboratoire Photonique, Numérique et Nanosciences, Bordeaux, France

Dirac points lie at the heart of many fascinating phenomena in condensed matter physics, from massless electrons in graphene to the emergence of conducting edge states in topological insulators. At a Dirac point, two energy bands intersect linearly and the particles behave as relativistic Dirac fermions. In solids, the rigid structure of the material sets the mass and velocity of the particles, as well as their interactions. A different, highly flexible approach is to create model systems using fermionic atoms trapped in an optical lattice, a method which so far has only been applied to explore simple lattice structures. In my talk I will report on the creation of Dirac points with adjustable properties in a tunable honeycomb optical lattice [1]. Using momentum-resolved interband transitions, we observe a minimum band gap inside the Brillouin zone at the position of the Dirac points. We exploit the unique tunability of our lattice potential to adjust the effective mass of the Dirac fermions by breaking the inversion symmetry of the lattice. Moreover, changing the lattice anisotropy allows us to move the position of the Dirac points inside the Brillouin zone. When increasing the anisotropy beyond a critical limit, the two Dirac points merge and annihilate each other. We map out this topological transition in lattice parameter space and find excellent agreement with ab initio calculations. Our results not only pave the way to model materials where the topology of the band structure plays a crucial role, but also provide the possibility to explore many-body phases resulting from the interplay of complex lattice geometries with interactions.

[1] Leticia Tarruell, Daniel Greif, Thomas Uehlinger, Gregor Jotzu and Tilman Esslinger, Nature *483*, 302–305 (2012).

Bloch-Zener Oscillations across a Merging Transition of Dirac Poins

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Cold atoms loaded in a tunable hexagonal optical lattice provide a new model system to study Dirac points [1]. By tuning the lattice parameters, Dirac points in the energy band structure can be manipulated by moving them and eventually, bringing them to a merging transition. The latter realizes a topological (Lifshitz) transition from a gapless phase with Dirac points to a gapped phase. To study such a system, Bloch-oscillation-type experiment has been performed with non-interacting fermionic atoms. Here, we provide a quantitative description of the experiment within the framework of a universal Hamiltonian for the merging transition [2,3]. Moreover, we study signatures for the the corresponding atomic Stückelberg interferometry.

[1] L. Tarruell, D. Greif, T. Uehlinger, G. Jotzu, T. Esslinger, Nature 483, 302 (2012)
[2] G. Montambaux, F. Piéchon, J.-N. Fuchs and M. O. Goerbig, Eur. Phys. J. B 72, 509 (2009)
[3] L.-K. Lim, J.-N. Fuchs, G. Montambaux, Phys. Rev. Lett. 108, 175303 (2012)

Ultracold Atoms in Disorder: 3D Localization and Coherent Backscattering.

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Phase coherence has dramatic effects on the transport properties of waves in random media, leading eventually to a complete halt of the wave, i.e. Anderson localization. For weak disorder, a first order manifestation of coherence is the phenomenon of coherent backscattering (CBS), i.e. the enhancement of the scattering probability in the backward direction, due to a quantum interference of amplitudes associated with two opposite multiple scattering paths.
Here I will report on the observations of 3D localization [1] and CBS [2] with ultra-cold atoms in a well-controlled laser speckle potential. The latter constitute the first direct signature of phase coherence in ultra-cold disordered gases (an independent and simultaneous experiment was reported in [3]) and may also provide an alternative probe to study strong localization effects [4]. Altogether, these results pave the way towards the precise investigation of the Anderson transition in 3D with ultra-cold atoms.

[1] F. Jendrzejewski, A. Bernard, K. Müller, P. Cheinet, V. Josse, M. Piraud, L. Pezzé, L. Sanchez- Palencia, A. Aspect and P. Bouyer, Three-dimensional localization of ultracold atoms in an optical disordered potential, Nature Physics 8, 398 (2012).
[2] F. Jendrzejewski, K. Müller, J. Richard, A. Date, T. Plisson, P. Bouyer, A. Aspect, V. Josse, Coherent Backscattering of Ultra-cold Atoms, Accepted to Phys. Rev. Lett. arXiv:1207.4775 (2012)
[3] G. Labeyrie, T. Karpiuk, B. Grémaud, C. Minitatura, and D. Delande, Coherent Backscattering of a dilute Bose Einstein Condensate, arXiv:1206.0845 (2012).
[4] T. Karpiuk, N. Cherroret, K. L. Lee, B. Grémaud, C. A. Müller, C. Miniatura, Coherent multiple forward scattering peak unveiled by Anderson localization, arXiv:1204.3451 (2012)

Mardi 16 Octobre 2012

Session 4 : Nanomécanique

A single nitrogen-vacancy defect coupled to a nanomechanical oscillator

S. Seidelin
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We present a novel hybrid system consisting of a single Nitrogen Vacancy (NV) defect hosted in a diamond nanocrystal positioned at the extremity of a SiC nanowire. The nanowire acting as a nanoresonator is probed via time resolved nanocrystal fluorescence and photon correlation measurements. By immersing the system in a strong magnetic field gradient, we obtain a clear signature of a magnetic coupling between nanoresonator and the NV electronic spin. This is a first step towards entering two new fields of physics: Single photon optomechanics and Spin based nanomechanics

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Dynamics and dissipation induced by single-electron tunneling in carbon nanotube nanoelectromechanical systems

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Carbon nanotubes have become an essential building block for nanoelectromechanical systems (NEMS). Their extraordinary mechanical and electronic properties provide for instance a strong electromechanical coupling compared to semiconductor based NEMS, which is key to various applications, for example high sensitivity mass or force sensing.1,2
Here we demonstrate the effect of single-electron tunneling (SET) through a carbon nanotube quantum dot on its nanomechanical motion at cryogenic temperatures. We find that the frequency response and the dissipation of the nanoelectromechanical system (NEMS) to single electron tunnelling strongly depends on the electronic environment of the quantum dot, in particular on the total dot capacitance and the tunnel coupling to the metal contacts.[3] Our findings suggest that one could achieve quality factors as high as 10^6 by choosing the appropriate gate dielectric and improve the tunnel coupling to the metal contacts. So far, we have achieved quality factors of 140000 at very low temperature, which is the highest value reported for carbon based NEMS at cryogenic temperatures.[2]

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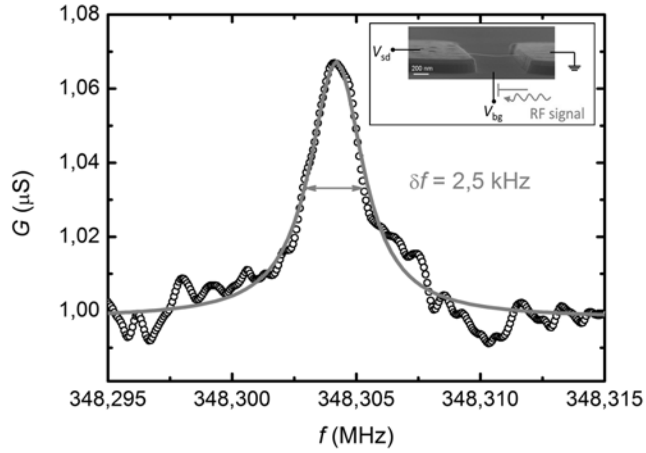

A carbon nanotube NEMS (inset) and its mechanical resonance yielding Q = 140000

Mardi 16 Octobre 2012

Session 4 : Nanomécanique

Ultrasensibility of nanoresonators (Carbon NEMS)

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The emergence of mechanical resonators systems in mesoscopic physics, optics and surface science corresponds to various applications in low noise amplifier, non-linear systems, filters or ultrasensible detectors. Good examples are graphene and carbon nanotubes wich are excellent materials for the fabrication of nanoelectromechanical systems (NEMS). Their large stiffness allows to build high frequency mechanical resonators. Their low density makes them sensitive to minute variations of mass and charge. In addition to having outstanding mechanical properties, these materials owe part of their uniqueness to their simplest feature: they constitute the ultimate size limit for one and two-dimensional (1D and 2D) NEMSs.
Recent improvement in the fabrication allows us to obtain high purity samples with low dissipation (Q>10E5 at 100mK) and GHz frequencies (11GHz).
Our measurements signal also an unprecedented scenario, where mechanical dissipation is determined by non-linear damping. All these steps allowed us to reach the yoctogram resolution (10E-24g) of an adding mass on top of these NEMS and to explore new aspects of surface physic.

A local optical probe for measuring motion and stress in a nanoelectromechanical system

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Nanoelectromechanical systems (NEMS) can be operated as ultrasensitive mass sensors and radio frequency resonators, and are to explore fundamental physical phenomena such as nonlinear damping and quantum effects in macroscopic objects. Various dissipation mechanisms are known to limit the mechanical quality factors of NEMS resonance and to induce aging due to material degradation. Therefore there is a need for methods that can probe independently the motion of these systems, and the local stress at the nanoscale. Here, we report a non-invasive local optical probe for the quantitative measurement of motion and stress within a NEMS based on Fizeau interferometry and Raman spectroscopy. The system consists of a multilayer graphene resonator that is clamped to a gold film on an oxidized silicon surface. The resonator and the surface both act as mirrors and therefore define an optical cavity. Fizeau interferometry provides a calibrated measurement of the motion of the resonator, while Raman spectroscopy can probe the strain within the system and allows a purely spectral detection of mechanical resonance of a NEMS.

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Mercredi 17 Octobre 2012

Session 5 : Matière topologique et Graphene

Diverses sondes pour la matière topologique

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Les isolants topologiques réalisent de nouvelles phases de la matière électronique, isolantes dans le volume et conductrices au bord ou à la surface de l'échantillon [1,2], une situation qui rappelle les états de bord de l'effet Hall Quantique. Cependant contrairement à l'effet Hall, ce métal de bord est réalisé en champ magnétique nul et trouve son origine dans un fort couplage spin-orbite. La propriété essentielle de ce métal de bord est l'existence d'un seul état de spin par direction de propagation.
Dans une première partie, j'introduirai très brièvement les isolants topologiques en prenant le graphène comme fil conducteur.
Dans la seconde partie, je présenterai nos travaux théoriques sur les états de bord métalliques des isolants topologiques 2D et leur couplage à diverses perturbations-sondes (magnétisme ou supraconductivité de proximité, couplage Rashba [3], onde électromagnétique [4]). Le but est de proposer des idées d'expériences qui permettraient de mieux établir et caractériser les propriétes de ces nouveaux conducteurs d'interface (aussi appelés conducteurs holographiques).

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Band structure on strained HgTe Topological Insulator

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Topological Insulators (TI) are a new class of materials that have been recently of great interest both theoretically and experimentally. These systems are defined by an inversion of the band structure at the time reversal symmetry point Γ. Intrinsically, they remain insulating in the bulk. The non-trivial properties arise on the interface with another topological class material : the surface becomes metallic, with massless Dirac fermions and non dispersive transport.

Due to its strong spin-orbit interaction, HgTe is a semi-metal with such a band structure inversion around the point Γ and is a very promising strong Topological Insulator. In order to unveil its non-trivial topological properties, HgTe samples are synthesized with a uniform strain that opens a gap by Molecular Beam Epitaxy method by P. Ballet (CEA/Leti).
Angle-Resolved PhotoEmission Spectroscopy (ARPES), due to its thin depth sensitivity, is a dedicated technique to study the protected surface states that occurs on interfaces between two systems of different topological classes and has already given convincing results on Bi_2Se_3 Ti systems.

Our recent ARPES results on HgTe, show clearly a Dirac cone of surface states which Dirac point lies just below the top of the Γ_8 heavy hole band. The observed strain induced gap ~60-80 meV is larger than expected, signaling the presence of some band bending close to the surface. Using circular polarization, we find a strong circular dichroism of the surface states, which proves their chiral nature. Finally, the surface states can be followed throughout the Brillouin zone. In the Γ-X direction, they connect these symmetry point with a straight line. In other directions, the surface states simply connect the two inverted bands as expected.

Mercredi 17 Octobre 2012

Session 5 : Matière topologique et Graphene

Hot electron cooling in graphene

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We have investigated the energy loss of hot electrons in graphene by means of GHz noise thermometry.
For phonon temperatures larger than Bloch-Grüneisen temperature, we find the energy relaxation rate J obeys a cubic law as a function of electron temperature Te.
In this regime, the small Fermi surface of graphene drastically restricts the allowed phonon energy in ordinary electron-phonon scattering,
and disorder-assisted super collisions dominate over the conventional electron-phonon collisions.
Below the Bloch-Grüneisen temperature, we regain $J \propto Te^4$ dependence, which is the signature of standard electron-phonon interaction in the 2D graphene [1].
Beside its implication for electron-phonon physics, our observations are of direct relevance for the performance of graphene bolometers and photo-detectors.

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Low temperature dephasing in graphene

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We address experimentally the problem of low temperature saturation of dephasing in graphene. This saturation was reported by several groups below a few hundreds of milliKelvin over the past few years using weak localization measurements. By combining weak localization and universal conductance fluctuations studies we demonstrate that: 1) the saturation is not due to experimental artifacts (thermalization issue, sample size); 2) paramagnetic impurities do play a role in the saturation as it was found in metals a decade ago; 3) an additional non-magnetic mechanism is involved but its exact nature remains to be determined

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Edge magneto-plasmons in graphene

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We present the observation of chiral Edge Magneto-Plasmon (EMP) propagation in graphene in the Quantum Hall regime. The measurement of the group velocity and its dependence on filling factor provides the first measurement of the drift velocity of carriers along the quantum Hall edge[1]. EMP are quasi one dimensional collective modes which are split off from the bulk magneto-plasmon modes by the sample boundary[2,3]. Closely confined to the edge as frequency is increased, they are a tool of choice to investigate edge structure and dynamics. The group velocity has two contributions, arising from the Hall conductivity and the carrier drift at the edge. In graphene, due to the particular dynamics and the abrupt edge, the drift velocity is expected to be of the order of the Fermi velocity[4]. We show EMP to exist by timing the travel of narrow wave-packets on picosecond time scales around exfoliated samples. We find chiral propagation with low attenuation at a velocity which is quantized on Hall plateaus. The carrier drift contribution from the EMP propagation is extracted and found to be slightly less than the Fermi velocity, as expected for an abrupt edge. We also extract the spatial spread of edge accumulated charge and find it to be narrower than for soft edge systems.

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Mercredi 17 Octobre 2012

Session 5 : Matière topologique et Graphene

The electronic structure of F and H on graphene and their effect on graphene's transport properties

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Using density-functional-theory, Hartree-Fock, exact-diagonalization, and numerical-renormalization group methods, we study the electronic structure of diluted F [1] and H [2] atoms chemisorbed on graphene. A comparison between DFT and Hartree-Fock calculations allows us to identify the main characteristics of the electronic structure of the defect. We use this information to formulate an Anderson-Hubbard model that captures the main physical ingredients of the system while still allowing a rigorous treatment of the electronic correlations. In addition, we study the transport properties of graphene in the strongly localized regime (induced by F impurities) where transport is characterized by the Mott variable range hopping regime and discuss it on the light of recent magneto-transport experiments [3].

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Mercredi 17 Octobre 2012

Session 6 : Spintronique

Theoretical aspects of spintronic phenomena in magnetic tunnel junctions and graphene based structures

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The discoveries of giant magnetoresistance(GMR) [1] in magnetic multilayers and of tunnel magnetoresistance [2] (TMR) in magnetic tunnel junctions (MTJ) generated a new field of research called spin electronics (spintronics) [3]. In this field, it is not only the electron charge but also the electron spin that is used to operate a device.
This presentation will be devoted to an overview of spintronic phenomena in magnetic nanostructures. First, recent progress in theory of spin transfer torques (STT) in MTJs will be presented which in particular allowed prediction of STT voltage dependences and provided solutions for STT-MRAM [4,5].
Next part of the talk will be devoted to studies of interlayer exchange coupling (IEC) using ab-initio and tight-binding approaches. In particular, the impact of structural relaxation and interfacial oxidation conditions on amplitude of IEC in MTJs will be addressed [6] as well as the importance of occupation numbers (Fermi level) on period of IEC oscillations as a function of ferromagnetic electrode thickness [7,8].
I will continue with ab-initio investigations of perpendicular magnetic anisotropy (PMA) at Fe(001)|MgO(001) and Co(001)|MgO(001) interfaces along with identifying mechanisms responsible for the PMA [9]. It will be demonstrated that the oxidation conditions strongly affect the PMA and it strongly correlates with tunnel magnetoresistance (TMR) in agreement with experiments [9,10].
The talk will be concluded by first-principles investigations of magnetic properties of graphene-based structures in a view of graphene spintronics including Co|graphene interfaces [11,12] and substrate and shape induced magnetism in graphene [13].

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Non linear magnetization dynamics driven by the interaction between spin current and magnetic moments

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Spin injection and detection with a single Kondo atom

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The ability to build well-calibrated junctions with a single atom bridging two electrodes of different geometry and chemical nature represents an opportunity for examining spin transport at the smallest possible length scales. Here we report the atomic-scale detection of a spin-polarized current flowing between a ferromagnet and a nonmagnet. For this purpose, we coat the bulk ferromagnetic tip of a scanning tunneling microscope with nonmagnetic copper and perform a stable quantum-point contact with a single cobalt atom adsorbed on a Cu(100) surface. The presence of a spin-polarized current across the nonmagnetic copper is probed through the Kondo effect of the Co atom as the current densities are sufficiently high to promote a splitting of the Kondo resonance. Our findings show that spin injection into a single atom is feasible and that, moreover, it can be controlled by altering the chemical properties of the contact.

Jeudi 18 Octobre 2012

Session 7 : Transport quantique

Transport mésoscopique dans un réseau semiconducteur étudié par microscopie à grille locale (SGM)

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Dans le domaine classique, il existe des configurations de réseaux (sociaux, mécaniques, électriques) dont le comportement est paradoxal lorsqu'une branche est ajoutée au réseau. Le paradoxe de Braess décrit ainsi l'augmentation paradoxale du temps de trajet d'un réseau routier lorsqu'une nouvelle route transverse est créée. Par curiosité, nous avons étudié la transmission quantique au travers d'une structure mésoscopique formée de trois canaux parallèles, connectés aux réservoirs source/drain par une même entrée et une même sortie placées de manière asymétrique, pour voir si la présence du canal central pouvait paradoxalement réduire la transmission globale du réseau. Grâce à des simulations de transport quantique balistique et cohérent, nous avons montré qu'un tel effet pouvait se présenter et nous avons tenté d'y apporter une interprétation en terme de trajectoires défavorisant la transmission globale.

D'un point de vue expérimental, nous avons fabriqué un tel réseau mésoscopique à trois branches par gravure d'une hétérostructure de semiconducteurs III-V formant un gaz d'électrons bidimensionnel (2DEG) de haute mobilité. Grâce à la pointe d'un microscope AFM cryogénique (4,2 K) fonctionnant en mode Scanning Gate Microscopy (SGM), nous avons modulé la transmission du canal central par effet de grille local et observé des variations non monotones de la conductance en fonction de la tension appliquée sur la pointe. Les modulations observées ne pouvant être expliquées par des effets d'interférences de type Aharonov-Bohm ou fluctuations universelles de conductance, nous proposons d'interpréter ces diminutions paradoxales de la conductance lors d'un élargissement du canal central, par un effet de type "paradoxe de Braess mésoscopique" tel que mis en évidence dans les simulations.

Il est toutefois important de noter que le désordre n'est pas négligeable dans ces échantillons, ainsi que l'ont révélé les images de microscopie SGM. Nous montrerons ainsi que les pièges de charges et les fluctuations de potentiel influencent le transport des électrons dans le gaz 2D. La charge portée par ces pièges change de manière discrète en variant la distance pointe-piège ou la tension sur la pointe, comme avec une boite quantique. Cet effet de blocage de Coulomb génère, sur les images SGM de transconductance, un ensemble de cercles concentriques centrés sur les pièges. Nous discutons de l'origine possible de ces pièges dont l'importance est cruciale pour la compréhension de l'origine du désordre et de son influence sur le transport mésoscopique.

Mutation of Andreev bound states into Majorana states in long NS and SNS junctions

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We study one-dimensional topological NS and SNS long junctions obtained by placing a topological insulating nanowire in the proximity of either one or two SC finite-size leads. We define a Majorana polarization order parameter and we use it to characterize the NS and SNS junctions. This analysis shows that the extended Andreev bound states of the normal part of the wire acquire a finite Majorana polarization: for a finite-size SN junction the Andreev bound state spectrum exhibits a zero-energy extended state which carries a full Majorana fermion, while the Andreev bound states of long SNS junctions with phase difference of pi transform into two zero-energy states carrying two Majorana fermions with the same Majorana polarization.
Given their extended character inside the whole normal link, these Majorana-Andreev states can be directly detected in tunneling spectroscopy experiments.

Jeudi 18 Octobre 2012

Session 7 : Transport quantique

Transmission phase in the Kondo regime revealed in a true two-path interferometer

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The Kondo effect in quantum dots has been intensively studied over the past decade since it is an archetype for correlated many-body effects. In particular, the phase shift of an electron when scattered off a quantum dot with Kondo correlation has attracted special interest as the observation of the theoretically predicted π/2-phase shift gives direct evidence of the many-body singlet state. However it is difficult to reveal the bare quantum phase of an electron wave with a "standard" Aharonov-Bohm (AB) interferometer due to boundary conditions from current conservation and time reversal symmetry [1]. So far only two groups have reported the phase shift related to the Kondo effect [2, 3, 4]. Here we report the direct observation of the transmission phase shift through a Kondo correlated quantum dot employing a new two-path interferometer realized in an AB ring with tunnel-coupled wires [5]. We see clear features of the Kondo correlation in the phase shift as expected from theory and in contrast with previous reported results [2, 3]. In addition, when increasing the temperature compared to T_K the phase shift in the valley already starts to deviate from the π/2-plateau at $T/T_K \sim 1$, which is different from the results reported in Ref. 3. For $T/T_K >> 1$ the phase shift evolves into a S-shape locked around π/2, which can be consistently explained with NRG results.

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Transmission phase in quantum transport: effects of disorder, chaos and electronic correlations

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The transmission phase of a coherent conductor is of fundamental importance in quantum transport. Unlike the conductance, the phase is not directly measurable. Nevertheless, phase-sensitive experiments have been performed by embedding a quantum dot in one arm of an interferometer. These experiments have observed in-phase behavior between consecutive Coulomb-blockade resonance peaks whose explanation has remained as a puzzle for more than a decade.
We provide a solution of this puzzle by showing that wave-function correlations existing in chaotic ballistic quantum dots are responsible for the emergence of large universal sequences of in-phase resonances in the short wavelength limit [1]. On the other hand, in disordered quantum dots the corresponding wave-function correlations decay on the scale of the elastic-mean-free path, and consecutive resonances exhibit random relative phases.
In quantum dots with many electrons the description of Coulomb blockade physics within a constant charging energy model allows for an effective one-particle description. Small dots require going beyond mean-field approaches by including the effect of electronic correlations. We undertake this study from a numerical viewpoint showing that small dots are always in the mesoscopic regime characterized by random relative phases [2].

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A two-atom electron pump

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Shrinking down the dimensions of classical microelectronics transistors has opened opportunities to electrically contact single donor atoms in silicon nanostructures [1, 2]. We demonstrate the next degree of complexity in donor-based electronics, namely a system of two coupled donors. Our 3-gate silicon nanostructure allows controlling independently the energy levels of two phosphorus donors, in series between source and drain electrodes. This device was used recently to measure the separation between the two first states of a donor [3]. Beyond this new spectroscopy technique, this coupled atom transistor provides unprecedented functionalities because we are now able to manipulate a single electron over two donors.

Here we demonstrate electron pumping through two phosphorus donors in series, with an appropriate gate driving [4]. We show both adiabatic and non-adiabatic regimes by changing the driving frequency. While quantized pumping is achieved in the low frequency adiabatic regime, we observe remarkable features at higher frequency when the charge transfer is limited by the different tunneling rates. We reproduce in details the characteristic signatures observed in the non-adiabatic regime by using a master equation, including the tunnel couplings. The transitions between quantum states are modelled involving a Landau-Zener transition.

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Session 8 : Transport quantique micro-ondes

Dynamical Coulomb blockade of the high frequency noise of a tunnel junction

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The transport properties of a quantum conductor are deeply modified when it is embedded in a circuit. Quantum fluctuations of the electromagnetic environment can trigger inelastic electron scattering giving rise to non-linear I(V) characteristics for the embedded conductor. This phenomenon, called Dynamical Coulomb Blockade (DCB), has been thoroughly investigated for tunnel junctions in the past decade [1], but only focusing on the corrections to the mean current. Besides, recent experiments carried on atomic contacts [2] and quantum point contacts [3,4] have shown that the corrections to the non-interacting I(V) characteristics do not only depend on the strength of the environment phase fluctuations, but also on the shot noise triggered by the conductor itself, in agreement with recent theoretical work [5-8]. A question that naturally arises is therefore: how does the DCB modify the current fluctuations of the conductor?

To investigate this question, we have embedded a tunnel junction in a microwave quarter-wave resonator which implements a "single-mode" electromagnetic environment. With such circuit, we can both measure the I(V) characteristic of the junction and the shot noise emitted by the junction at microwave frequencies (~6GHz). But obtaining strong DCB effects requires the resonator to display a characteristic impedance comparable to the resistance quantum (h/e^2~26kOhm), which is hardly achievable by exploiting plain geometric considerations. We have taken advantage of the kinetic inductance of an array of Josephson junctions, to increase up to ~1.5 kOhm the characteristic impedance of an otherwise standard coplanar waveguide. The resulting coupling is strong enough to observe DCB corrections to the shot noise emitted by the tunnel junction, interpreted as spontaneous two-photon emission processes. Thanks to an independent calibration of the resonator, we can reproduce the DCB corrections to the shot noise with the help of recent theory [9].

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Jeudi 18 Octobre 2012

Session 8 : Transport quantique micro-ondes

Stabilizing the trajectory of a superconducting qubit with projective quantum feedback

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Recently, research on quantum physics has moved from only demonstration of subtle quantum phenomena to engineered systems benefiting from quantum laws peculiarities. Quantum measurements being non-deterministic, it is mandatory to develop feedback procedures in the aim of building predictable quantum machines. Feedback is made possible by the fact that the measurement record contains all the necessary information to follow the quantum state of the system in real time.
In this talk, I will present a recent experiment where a superconducting qubit is controlled by a projective measurement based feedback. We demonstrate efficient qubit reset and trajectory stabilization using the information extracted from a Quantum Non Demolition projective measurement.
This experiment benefits from 3 recent breakthroughs. First, we use the recently developed 3D transmon superconducting qubits, with several tens of microseconds coherence times [1]. Second, the detector for the qubit pointer states, which are a few microwave photons large coherent states, is a phase preserving parametric amplifier operating close to the quantum limit and recently developed in our group [2]. Third, the feedback loop can be performed with a delay of a fraction of a microsecond using a digital filter implemented on innovative fast electronic digital processors, namely Field-Programmable-Gate-Arrays (FPGA). In this experiment we combine these three ingredients to realize a test bed for measurement based feedback. As a first illustration of its abilities, we demonstrate high fidelity qubit state preparation, approx. 99% for the ground state and approx. 95% for the excited state. We also demonstrate the perpetual stabilization of Rabi oscillations, with fidelity above 80%.

[1] H. Paik /et al./, *Phys. Rev. Lett.* 107, 240501 (2011)   [2] N. Roch /et al/., *Phys. Rev. Lett.*108, 147701 (2012)

The Josephson mixer, a Swiss Army Knife for microwave quantum optics

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The possibility to couple various mesoscopic systems to microwave signals and the availability of high performance microwave instruments make microwave quantum optics a very promising component for future quantum machines. In this talk, I will present how the Josephson mixer can fill several roles in the toolbox of microwave quantum optics. When the pump tone is the sum of the two other mode frequencies, it acts as a phase-preserving quantum limited amplifier [1]. When only vacuum fluctuations feed its two ports, it produces Einstein-Podolsky-Rosen (EPR) states of microwave light shared over two transmission lines at arbitrarily separated mode frequencies. Using a noise-interferometric experiment, we were able to demonstrate a production rate of more than 6 millions entangled bits per second, comparable to current achievements in optics [2]. When the pump tone is the difference of the two other mode frequencies, it acts as a dissipationless up or down-converter for microwave signals. Coupling the mixer to an isolated resonator on one port, we were able to make a quantum memory for microwaves. The memory can hold a quantum signal as long as the internal losses of the resonator permit and can be written and read on-demand at a rate given by half that of the other port's coupling.

[1] Roch, Flurin et al, PRL (2012)
[2] Flurin et al, ArXiv (2012)

Jeudi 18 Octobre 2012

Session 8 : Transport quantique micro-ondes

Single electron experiments in a quantum Hall device

E. Bocquillon1, V. Freulon1, F. D. Parmentier1,4, C. Grenier2, P. Degiovanni2, J-M Berroir1, D. C. Glattli1,3, B. Plaçais1, G. Fève1, A. Cavanna4, Y. Jin4
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3 Service de Physique de l'Etat Condensé, CEA, 91192 Gif-sur-Yvette, France.
4 Laboratoire de Photonique et Nanostructures, UPR20 CNRS, Route de Nozay, 91460 Marcoussis Cedex, France

The ballistic propagation of electronic waves in the quantum Hall edge channels of a 2DEG bears strong analogies with photon optics. Ballistic and one-dimensional propagation are ensured by the chiral quantum Hall edge states and electronic beam splitters can be implemented using quantum point contacts. These analogies have inspired a whole set of experiments, including the realization of electronic Mach-Zehnder [1] and Hanbury-Brown & Twiss [2] interferometers.
So far, these experiments have been performed with continuous dc sources lacking the necessary timing to manipulate single electron states on a controlled manner. The realization of on-demand single electron emitters [3,4] has risen the hope to reach, in these experiments, the single charge control. We will present the realization of two quantum optics like experiments at the single electron scale.
In the Hanbury-Brown & Twiss experiment [5], single elementary electronic excitations are partitioned, on an electronic beam-splitter. We show that the measurement of the output currents correlations in the HBT geometry provides a direct counting, at the single charge level, of the elementary excitations (electron/hole pairs) generated by the emitter at each cycle. We observe the antibunching of low energy excitations emitted by the source with thermal excitations of the Fermi sea already present in the input leads of the splitter, which suppresses their contribution to the partition noise. This effect can be used to probe the energy distribution of the emitted wave-packets which can be tuned by varying the emitter parameters.

In the Hong-Ou-Mandel experiment [6], two time-delayed mono-electronic excitations collide on a beamsplitter. If electrons are emitted in the same quantum state, a reduction of the output correlation is observed for zero time-delay as *indistinguishable fermions antibunch. The coherence time, corresponding to the temporal width of the wavepackets can be obtained from the dependence of the output noise with the time-delay between sources.*

[1] Ji et al., Nature 422, 415 (2003)
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[3] Fève et al., Science 316, 1169 (2007)
[4] Leicht et al., Semiconductor Science and Technology 26, 055010 (2011).
[5] Bocquillon et al., Physical Review Letters 108, 196803 (2012)

18h ***Départ d'Aussois, train Modane – Paris à 19h20***

Résumés POSTERS

Quantum Transport and Electromechanical Properties of Josephson Junctions made of Carbon Nanotube Quantum Dots

Rémi Avriller[1] and Fabio Pistolesi[1],

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Due to their fascinating electronic and mechanical properties [1], carbon nanotubes (CNTs) are ideal candidates to design new carbon-based nano-electromechanical systems (NEMS). Recent experimental activities emerged that realized ultra sensitive mass/force detectors based on such suspended carbon nanotubes [2].

The case where the source and drain electrodes are superconductors (thus realizing a Josephson junction) should present similar electromechanical effects, although more complex [3,4,5]. In this theoretical work, we present quantitative predictions for the dc and ac contribution to the supercurrent induced by the movement of an oscillating CNT in a Josephson junction setup [5].
Actuation of the CNT is done upon applying an ac gate voltage $V_g(t)$ oscillating at a frequency ω, show that the dc Josephson current I_{dc}(□□) an anti-resonance when the frequency of the oscillator ω the distance ω_A between the Andreev states located inside the superconducting gap. We analyze the current-phase characteristics I_{dc}(□□) a function of the parameters describing the junction. The transition to the □̃[6] of the junction is also explored in presence of mechanical oscillations.

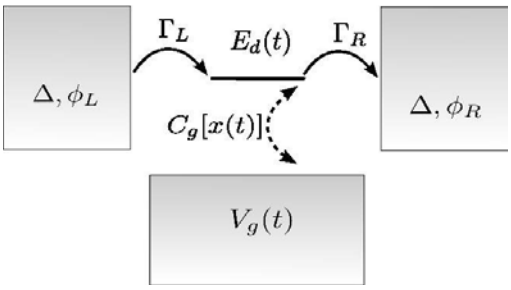

Fig.1 : Model of a vibrating CNT quantum dot [5].

[1] J.-C Charlier, X. Blase, and S. Roche, Rev. Mod. Phys. 79, 677–732 (2007). Lassagn .B [2]*et al.* ,Science ,***325***-1107 , Steele .A.G ;(2009) 1110*et al.* ,Science ,***325***.(2009) 1107-1103 ,
[3] R. AVRILLER, F. S. BERGERET, AND F. PISTOLESI, PHYS. REV. B 84, 195415 (2011).
[4] C. Padurariu, C.j.H. Keijzers and Yu. V. Nazarov, arXiv:1112.5807v1(2011).
[5] R. Avriller, and F. Pistolesi, in preparation.

Non-equilibrium josephson effect through helical edge states"

D. Badiane

CEA/INAC/SPSMS, 17 rue des martyrs, Grenoble

We study Josephson junctions between superconductors connected through the helical edge states of a two-dimensional topological insulator in the presence of a magnetic barrier.
As the equilibrium Andreev bound states of the junction are 4-pi periodic in the superconducting phase difference, it was speculated that, at finite dc bias voltage, the junction exhibits a fractional Josephson effect with half the Josephson frequency. Using the scattering matrix formalism, we show that his effect is absent in the average current. However, clear signatures can be seen in the finite-frequency current noise. Furthermore, we discuss other manifestations of the Majorana bound states forming at the edges of the superconductors.

Scattering Gate Interferometry at a Quantum Point Contact

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(1) Institut Néel (CNRS-UJF), 25 rue des Martyrs 38042 Grenoble

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(3) Laboratoire de Photonique et de Nanostructures (CNRS), Route de Nozay 91460 Marcoussis

The aim of our collaborative ANR project ITEM-exp is to investigate the electron-electron interactions in mesoscopic physics, especially in quantum point contacts (QPC) at low electron density. We pay particular attention to the so-called "0.7 anomaly" which is thought to result from these interactions. In our experiments, we use a non-local scatterer of the QPC transmission to control the electron density in the QPC by means of Friedel oscillations. This experimental project has been stimulated by the theoretical work done within the ANR project ITEM-theory. Samples are prepared in high mobility layers at LPN, transport measurements are done in dilution fridge at INAC, and future SGM experiments will be done at NEEL. In the poster, we present first promising results of an innvovative technique using an additionnal thin gate, one micron away from the QPC, to backscatter the electrons towards the QPC and produce interferences. We find that the amplitude and phase of these interferences change with the QPC transmission and show a small enhancement at the "0.7 anomaly"

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*Mutation of Andreev into Majorana bound states in long NS and SNS junction*s

D. Chevallier

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We study one-dimensional topological SN and SNS long junctions obtained by placing a topological insulating nanowire in the proximity of either one or two SC finite-size leads. Using the Majorana Polarization order parameter (MP) introduced in Phys. Rev. Lett. 108, 096802 (2012), we find that the extended Andreev bound states (ABS) of the normal part of the wire acquire a finite MP: for a finite-size SN junction the ABS spectrum exhibits a zero-energy extended state which carries a full Majorana fermion, while the ABS of long SNS junctions with phase difference _ transform into two zero-energy states carrying two Majorana fermions with the same MP. Given their extended character inside the whole normal link, and not only close to an interface, these Majorana-Andreev states can be directly detected in tunneling spectroscopy experiments

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Superconductor-Insulator Transition in amorphous NbSi thin films

F. Couëdo

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We report on the study of a disorder-induced Superconductor to Insulator Transition (SIT) in amorphous NbSi thin films. By increasing the annealing temperature of an initially superconducting film, transport measurements show the appearance of a resistive state at low temperatures, revealing the destruction of the superconducting ground state. Our interpretation of this disorder-induced superconducting to non-superconducting quantum phase transition is that annealing increases the microscopic disorder by modifying quantum interference patterns. Because it can drive the same sample towards the SIT, annealing thus appears to be relevant for the study of the effects of disorder on superconductivity.

Epitaxie de couches minces supraconductrices de rhénium sur saphir

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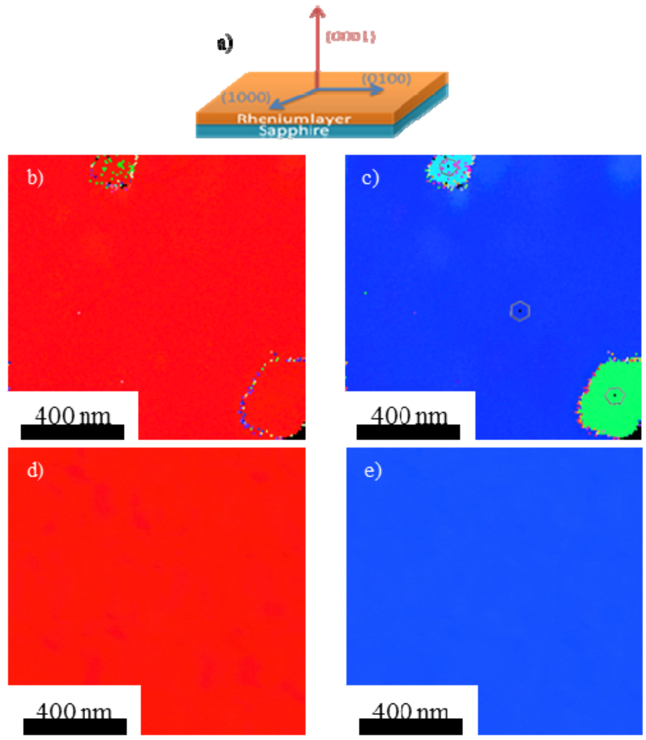
Les dispositifs supraconducteurs les plus souvent utilisés sont réalisés à base d'aluminium ou de niobium. Dans les jonctions Josephson, la barrière tunnel est réalisée par oxydation de l'aluminium polycristallin. Nous présentons nos travaux sur le dépôt de couches minces monocristallines de rhénium sur un substrat de saphir (Al_2O_3-α) par épitaxie par jet moléculaire. Des couches de rhénium supraconductrices devraient permettre la réalisation de barrière tunnel en oxyde d'aluminium épitaxié. Cette technique nous permet d'avoir des dépôts de très haute pureté et de très haute qualité cristalline. Il existe un très bon accord entre les paramètres de maille du Rhénium et du Saphir selon le plan (0001), ce qui permet une épaisseur critique de dépôt de près de 30 nm. Au-delà de cette épaisseur, les contraintes élastiques liées au désaccord de paramètre de maille sont relaxées sous forme de dislocations. La température de croissance contrôle la qualité cristallographique. Elle doit être au moins de 850°C[1]. Un travail important a été fait sur la préparation de l'état de surface du substrat et sur les conditions de dépôt pour obtenir de meilleurs échantillons. Des analyses en diffraction X ainsi que des images en EBSD (Electron Back Scattering Diffraction) sont utilisées pour contrôler la qualité cristallographique des échantillons. L'EBSD est une technique utilisée en microscopie électronique à balayage pour imager localement l'orientation cristallographique de l'échantillon, au moyen d'une caméra qui visualise les lignes de Kikuchis dues à la diffraction des électrons avec la surface. Les images ci-dessous proviennent des analyses EBSD de deux échantillons et révèlent l'orientation cristalline en surface comme illustré par l'image a).



Cartographie EBSD de deux échantillons de rhénium sur saphir.
a): Schéma de l'échantillon et des directions cristallographiques étudiées.
b) et d) : Selon la direction de croissance de la couche de l'échantillon 1 (b) et de l'échantillon 2 (d)
c) et e) : En fonction des directions dans le plan de la couche de l'échantillon 1 (c) et de l'échantillon 2 (e)

L'image b) représente l'orientation cristallographique de la couche de Rhénium dans l'axe de croissance (couleur rouge). On observe des joints de grains désorientés par rapport à cet axe (0001). L'image c) représente la même zone en fonction d'une direction cristallographique dans le plan. On observe des nano-grains (couleur verte et bleu verte). Ces deux domaines sont désorientés dans le plan (comme montré par les hexagone dessiné). Ces désorientations dans le plan sont de +/-30 degrés (variants). L'optimisation de l'état de surface des substrats et des conditions de dépots ont permis les images d) et e) où cette fois ci, l'ensemble de l'échantillon est correctement orienté selon l'axe de croissance, sans variant dans le plan de la couche mince. La cristallographie étant maintenant optimisée, la prochaine étape est l'amélioration de la surface de nos échantillons qui présentent actuellement une croissance en spirale dûe à l'émergence de dislocations [2]. Ces couches sont étudiées par Claude Chapelier du CEA pour la caractérisation par spectroscopie STM de la densité d'état électronique des vortex dans les couches minces de rhénium, Johan Coraux pour le dépôt de couches de graphène sur rhénium, Klaus Hasselbach pour l'étude des vortex par imagerie micro-SQUID et pour la fabrication d'un squid à base de tricouches Re/Al_2O_3/Re, et enfin la réalisation de jonction Josephson pour l'étude de qubits de phase avec Olivier Buisson.

[1] S. Oh, D.A. Hite, Thin Solid Films, 496, 2, 389-394 (2006)
[2] W.K. Burton, N. Cabrera, F.C. Frank, Phil. Trans. R. Soc. Lond. A 1951 243, 299-358

Probing the Dynamics of Andreev States in Coherent Normal/Superconducting ring

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When a normal metal wire is sandwiched between superconductors at low temperatures, a non-dissipative current can flow. The way this supercurrent responds to a dc phase difference φ, the current-phase relation, was only recently measured with a Hall probe[1]. It reflects the phase dependence of the Andreev bound states (ABS) , entangled electron-hole states which form in the normal metal as a consequence of the superconducting mirror-like boundary conditions. However little is known about the dynamics of these ABS and their relaxation.
In order to investigate the evolution of the current phase relation in such superconductor/normal metal/superconductor (SNS) junctions with high frequency phase driving, we have coupled one NS ring to a multimode superconducting resonator. The in-phase (□') and out-of-phase (□'') ac magnetic susceptibility of the ring is deduced from the dc flux dependence of the resonance frequency and quality factor of the resonances from 200 MHz up to 8 GHz. First results show the coexistence of a non-dissipative (□') and a dissipative (□'') response in the NS ring. Both exhibits sharp anomaly at $\varphi=\pi$ due to a dynamical contribution. This dynamical contribution is not negligible when phase modulation is faster than the inelastic relaxation time. Then populations have no time to relax and stay frozen at their dc value. This picture doesn't seem to hold at frequencies higher than the diffusion time.

[1] M. Fuechsle et al., Phys. Rev. Lett., 102, 127001 (2009)

Electron injection with Coulomb interactions

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Electron injection from a quantum dot with Coulomb interactions to a lead is studied using bosonization and Keldysh formulation of the multisite Fano-Anderson model. Charge relaxation is not always exponential depending on the transparency of the dot-lead barrier, size of the dot and
strength of the Coulomb repulsion.
The phase diagram is obtained. Results of Ref. 2 for current and noise are retrieved for moderately open and closed dots but new physics emerges for very open dots and also when Coulomb repulsion becomes important. Electron injection is not always ideal as in Ref. 1, we calculate the number of parasitic electron-hole pairs that are created.

[1] J. Keeling, A. V. Shytov, and L. S. Levitov, Phys. Rev. Lett **101**, 196404 (2008)
[2] F. D. Parmentier, E. Bocquillon, J.-M. Berroir, D. C. Glattli, B. Placais, G. Fève, M. Albert, C. Flindt, and M. Buttiker, Phys. Rev. **B 85,** 165438 (2012).
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Couplage entre un atome artificiel à effet Kerr et une cavité micro-onde

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Nous présentons une étude théorique mettant en évidence un nouveau système de mesure de l'état d'un Qubit basé sur le couplage entre un atome artificiel et une cavité micro-onde.
L'atome artificiel que nous présentons ici est beaucoup plus riche que les atomes artificiels précédemment étudiés avec en particulier, l'existance de deux degrés de libertés interne couplés. De plus l'Hamiltonien décrivant cet atome contient des termes de couplages non-linéaires dont un terme correspondant à l'effet Kerr croisé. Ce terme singulier modifie la fréquence propre d'un degré de liberté en fonction du nombre de quanta d'énergie contenue dans le second degré de liberté.
Nous avons étudié théoriquement la transmission d'un signal micro-onde à travers une cavité couplée à notre atome artificiel [1]. Le premier degré de liberté est fortement couplé à la ligne à transmission résonante. En fonction de l'état du second degré de liberté, le premier degré de liberté est dans le régime résonant ou dispersif avec le résonateur micro-onde. Cela conduit à une amplitude de signal micro-onde transmis très contrastée en fonction de l'état du second degré de liberté. Cette propriété pourrait être utilisée pour réaliser des mesures très rapides non destructrices avec une très grande fidélité. En utilisant les amplificateurs paramétriques Josephson, nous prédisons une fidélité de 99.9% pour un temps de mesure de 50ns.

[1] I. Diniz et al, papier soumis.

Centre NV unique couplé à un oscillateur nano-mécanique

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Les sytèmes hybrides opto-mécaniques sont en plein essors [1]. Un défi actuel est d'agir sur l'état d'un résonateur mécanique macroscopique et d'y créer des états quantiques arbitraires. Pour cela, un système à deux niveaux, facilement contrôlable, peut être utilisé pour coupler le résonateur au monde extérieur. Une première expérience [2] a récemment montré le couplage d'un nanofil (résonateur) à un centre NV (système à deux niveaux) en régime adiabatique.
Désormais l'objectif est d'une part d'explorer le régime non adiabatique, dit de bandes latérales résolues, qui pourra notamment être utilisé pour le refroidissement actif du résonateur. D'autre part il nous faut développer un accès au système hybride à travers le résonateur.
L'effet d'une oscillation mécanique, simulée par un champ RF, sur la photophysique du centre NV est étudié. En variant la fréquence du champ RF nous montrons le passage du régime adiabatique déjà observé expérimentalement [2] à un nouveau régime, dit de bandes latérales résolues. Dans ces deux régimes, les mesures de fluorescence du centre NV montrent un très bon accord avec les simulations numériques du système hybride.
Par ailleurs nous avons développé une méthode de lecture directe de la position du résonateur afin de sonder le système hybride à travers la dynamique de l'oscillateur sans perturber le centre NV. Un faisceau laser est fortement focalisé sur le nanofil, une photodiode à quadrant mesure l'intensité lumineuse transmise, renseignant ainsi la position du nanofil dans le faisceau laser. Une très grande sensibilité en déplacement, proche de la limite quantique standard, a ainsi été obtenue.

[1] K. Schwab *et al.* Physics Today **58**, 36 (2005)
[2] O.Arcizet *et al.* Nature Phys. **7**, 879 (2011)

Gaz de Bose unitaire, pertes à trois corps.

I. Ferrier-Barbut, B.Rem, A. Grier, U. Eisman, Tim Langen, N. Navon, Félix Werner, Dmitry Petrov, F. Chevy, C. Salomon
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Nous présentons une étude expérimentale et théorique du comportement des pertes à trois corps dans un gaz de Bosons unitaire. Ce travail permet de compléter les résultats existants sur la recombinaison à trois corps, cause des pertes dans un gaz de Bose. Nous adressons en effet le régime unitaire des collisions où la longueur de diffusion à deux corps a est infinie. Lorsque cette limite est atteinte le taux de recombinaison à trois corps présente une saturation à une valeur indifférente du signe de a. Ces résultats sont comparés à une théorie analytique et permettent d'obtenir des informations sur l'équilibre du gaz unitaire.

Quantum transport in spin glasses

G. Forestier
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The name of my poster is "Quantum transport in spin glasses". During the last decades, spin glass systems have been widely studied and nowadays it exists two antagonist descriptions for the low temperaure phase. The first is the mean field solution, where the broken symetry is non trivial and the ground state is composed of muliple states in a hierachical structure.
The second is "droplet" model, based on a non equilibrium of a unique state. With UCF, we propose a unique tool to investigate on the ground state, indeed UCF are magnetofingerprints for the microscopic disorder, so it gives access to the microscopic configurations of the magnetic impurities. Therefore, this poster presents how the use of UCF allows a detailed observation of the sample at the microscopic level, and how it is possible to investigate on the ground state.

Direct observation of neutral and charge modes in one dimensional chiral edge channels

E. Bocquillon[1], V. Freulon[1], P. Degiovanni[2], J.-M. Berroir[1], B. Plaçais[1], A. Cavanna[3], Y. Jin[3] , G. Fève[1]
1 Ecole Normale Supérieure, Laboratoire Pierre Aigrain, 24, rue Lhomond, 75231 Paris Cedex 05, France
2 Laboratoire de Physique de l'Ecole Normale Supérieure de Lyon ; 46 allée d'Italie, 69000 Lyon, France
3 Laboratoire de Photonique et Nanostructures, UPR20 CNRS, Route de Nozay, 91460 Marcoussis Cedex, France.

The propagation of electronic excitations along chiral quantum Hall edge channels has been thoroughly studied in the recent years in new electron optics experiments exploiting electron/photon analogies in this system. As examples, the electronic versions of Mach-Zehnder [1] or Hanbury Brown and Twiss [2] interferometers have been realized. However, contrary to photons, electrons interact with each other through the Coulomb interaction which strongly affects the coherence properties of electronic sources. In particular, at filling factor $\nu=2$, the dominant interaction mechanism results from the capacitive coupling between copropagating edge channels, as reported in Mach-Zehnder interferometers [3,4], and confirmed by energy relaxation measurements [5].

In this experiment, we investigate the coupling between two copropagating edge channels by measuring, in a wide frequency range going from 0.7 to 11 GHz, the transmission of charge density waves (or edge magnetoplasmons) from one edge to the other. A mesoscopic capacitor [6] is used to excite edge-magnetoplasmons of variable frequency, selectively in the outer channel and the resulting current in the inner channel is then collected after interaction on a length of a few microns. Damped charge oscillations between channels are observed, which can be explained by the existence of two eigenmodes of different velocities resulting from the interchannel coupling. The fast mode is a charge mode while the slow one is a neutral spin mode. Our experimental results are compared with theoretical models [7,8] providing a quantitative understanding of the coupling between the two edge channels and the resulting separation between the charge and neutral modes.

[1] Ji, Y., Chung, Y., Sprinzak, D., Heiblum, M., Mahalu, D., Shtrikman, H., Nature, 422(6930), 415-8 (2003).
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[3] Roulleau, P., Portier, F., Roche, P., Cavanna, A., Faini, G., Gennser, U., Mailly, D., Physical Review Letters, 100(12) (2008).
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[7] Levkivskyi, I.P., Sukhorukov, E.V., Physical Review B 78, 045322 (2008)
[8] Degiovanni, P., Grenier, C., Fève, G., Altimiras, C., le Sueur, H., PRB, 121302(R)(2010)

Time resolved simulations for quantum transport.

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In recent years, some experiments at the intersection of high frequency physics and mesoscopic physics have started to be realized. We developed a mathematical framework that describes the shape of the wave packets produced by a given voltage pulse applied to a quantum conductor. Now we need an efficient numerical tool to investigate the time resolved behavior of single particles in such experiments. Our approach has two main features. First, we want to solve the Schrödinger equation with correct initial conditions. This is achieved by considering voltage pulses instead of assuming an initial shape. Second, we take into account the Pauli principle and the statistical distribution (Fermi-Dirac). Different numerical approaches are discussed regarding their stability and costs in terms of memory and CPU usage.

Spin-dependent thermoelectric transport in HgTe/CdTe quantum wells

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We analyze thermally induced spin and charge transport in HgTe/CdTe quantum wells on the basis of the numerical non-equilibrium Green's function technique in the linear response regime. In the topologically non-trivial regime, we find a clear signature of the gap of the edge states due to their finite overlap from opposite sample boundaries - both in the charge Seebeck and spin Nernst signal. We are able to fully understand the physical origin of the thermoelectric transport signatures of edge and bulk states based on simple analytical models. Interestingly, we derive that the spin Nernst signal is related to the spin Hall conductance by a Mott-like relation which is exact to all orders in the temperature difference between the warm and the cold reservoir [1].

[1] D. G. Rothe, E. M. Hankiewicz, B. Trauzettel, and M. Guigou, Arxiv:1208.2197

Devices for microwave quantum optics based on single Cooper pair tunneling

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Cooper pairs can tunnel through a Josephson junction not only in the zero-voltage state but also at finite bias voltages V, when the Cooper pair energy $2eV$ can be absorbed by the electromagnetic environment of the junction. For small junctions in the single Cooper pair regime, the energy $2eV$ is not necessarily absorbed in the form of a single photon: In suitable electromagnetic environments multi-photon processes can dominate over single photon processes, thereby coupling different photon modes.
We want to exploit this physics for building devices for quantum optics in the microwave domain, generating and detecting propagating photons. Compared to existing devices based on Josephson junctions in the zero-voltage state, we expect shorter coherence times but much larger bandwidth and much higher operating frequencies, only limited by the gap of the superconductor.
We are building our devices using NbN-MgO-NbN tunnel junctions which should allow operation up to 1 THz, or 5 meV, bringing superconducting quantum circuits in the energy range of quantum dots and other mesoscopic devices.

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Gate-tunable localization effects in superconducting graphene junctions.

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Al/Ti/graphene/Ti/Al junctions with different graphene lengths (0.3, 0.7 and 1.3 μm) have been investigated on a single-layer exfoliated graphene flake. The measured differential resistance characteristics dV/dI(V) (voltage V, current I) show structures related to the Andreev reflection process and to the Josephson effect in the superconducting state below the critical temperature Tc = 600 mK of the Al/Ti contact electrodes. The observed zero-bias maximum in dV/dI(V) reveals a non-linear junction-length dependence, which points to a localization phenomenon. This phenomenon, possibly resulting from electron-electron interaction effects in diffusive transport, survives in the normal state of the contact electrodes and is reinforced by increasing the junction length and by tuning the back-gate voltage to the Dirac point with low charge-carrier density. The superconducting proximity effect allows to obtain information on the phase-coherent transport across the graphene junction

Electron and hole Hong-Ou-Mandel interferometry

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We consider the electronic analog of the quantum optics Hong-Ou-Mandel interferometer, in a realistic condensed matter device based on single electron emission in chiral edge states. For electron-electron collisions, we show that the measurement of the zero-frequency current correlations at the output of a quantum point contact produces a dip giving precious information on the electronic wavepackets and coherence. As a feature truly unique to Fermi statistics and condensed matter, we show that two-particle interferences between electron and hole in the Fermi sea can produce a positive peak in the current correlations, which we study for realistic experimental parameters.

Implementation and test of a Levitov n-electron coherent source

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Injecting a controlled number of n-electrons in a quantum ballistic conductor opens the way to new kind of quantum experiments, yet never done. It is well known that a voltage biased contact applied on a single mode quantum conductor, continuously injects single electrons at a rate eV/h. Here we consider the periodic injection of n-electrons using voltage pulses whose flux over one period is n.h/e. If the voltage pulse has a Lorentzian shape in time and n is integer, Levitov and collaborators showed that the n-electrons are not accompanied by extra neutral electron-hole pair excitations: this provides a n-electron minimal excitation coherent source [1]. We present here its first experimental realization using sub-nanosecond pulses [2]. To analyze the source, the n-electrons are send toward a quantum point contact (QPC) realized in clean 2DEG and the low frequency shot noise produced by the partitioning of the excitations is measured. As the shot noise counts the total number of excitations this allows to experimentally demonstrate that Lorentzian pulses do show minimal excitations as opposed to sine and square wave pulses. We analyze the electronic pulses in the energy domain using Shot noise spectroscopy. Finally, by colliding on the QPC two electronic pulse trains coming from opposite contacts and controlling their time delay, a time-domain analysis of the pulses is obtained by measuring the shot-noise reduction arising from fermionic antibunching when the time delay is reduced.

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2D electron interferometer: interaction and temperature effects

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We study a "toy" model of the scanning gate microscope (SGM), namely electron interferometer formed with 2 scatterers in a 2d lattice. The first one is made by a site of potential V_0, an Hubbard interaction U and coupling terms τ_C. The second one is just given by a site potential V, put at a distance R from the first one. One studies how varies the conductance G of this interferometer when R, U and the temperature T are varied. We demonstrate the scaling with temperature of the electron density inside the contact. The interaction driven effects are studied in the framework of the HARTEE-FOCK approximation [1], which however allows to calculate magnetization above the Kondo temperature [2]. One finds that G exhibit oscillations spaced by half the Fermi wavelength as R varies. When the first scatterer is at resonance, these oscillations can rise due to the interaction, similarly to the temperature driven effect described in [3]. In the local moment regime conductance at large distances ($R>>\lambda_F$) decays as 1/x with a Gaussian cut-off, while on the distances close to the contact it decays as $1/x^2$ due to the density modulation caused by the tip.

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Decoherence of the Majorana fermions

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Majorana fermion is one of the possible candidates for future quantum computation implementations. Of interest is their topological properties which protect them from decoherence. More precisely, the delocalization of the Majorana wave function at the two ends of a semi-conducting wire in the proximity with a superconductor allows the parity (i.e. number of fermions) to be conserved up to some exponential corrections.
We want to discuss the decoherence aspects of the Majorana fermion in general terms. To do that, we first establish a toy-model for the calculation of the wave function associated with a delocalized Majorana fermion. Then, we discuss the (gauge non-trivial) possibilities for exciting a proximity-induced superconductor. Finally, we discuss the decoherence characteristic times associated with several quantities, the most important of them being the parity of a given part of the wire.

*In collaboration with Fabian Hassler - Institute for Quantum Information, RWTH Aachen

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Superconducting proximity effect through long S/graphene/S junctions from zero field to the Quantum Hall regime[1]

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We investigate the superconducting proximity effect through graphene in the long diffusive junction limit, at low and high magnetic field. The interface quality and sample phase coherence lead to a zero-resistance state at low temperature, zero magnetic field, and high doping. We find a striking suppression of the critical current near graphene's charge eutrality point, which we attribute to specular reflection of Andreev pairs at the interface of charge puddles. This type of reflection, specific to the Dirac band structure, had up to now remained elusive. At high magnetic field, the use of superconducting electrodes with high critical field enables the investigation of the proximity effect in the quantum Hall regime. Although the supercurrent is not directly detectable in our two-wire configuration, interference effects are visible which may be attributed to the injection of Cooper pairs into edge states.
Another experiment is brought out in graphene with metalloporphyrins molecules, which gives rise to a charge exchange between the molecular and graphene by the formation of magnetic singlet in the molecular. The magnetism eliminates the supercurrent in electron doped region and it can be revealed by the presence of a sizable hysteretic magnetoresistance in the electron doped region.

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BEC in a highly anisotropic dressed quadrupole trap

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We demonstrate the trapping of a Rb87 Bose-Einstein condensate in a very anisotropic radio-frequency (RF) dressed quadrupole trap. The condensate is first produced in a magnetic quadrupole trap plugged in its center by a blue detuned laser, carefully optimized to overcome Majorana losses[1]. This trap is characterized by the measure of the oscillation frequencies and the bottom frequency.
Once condensed, the atoms are transferred to the dressed trap by sweeping the RF frequency and removing slowly the plug laser. In the dressed trap, the RF coupling is precisely determined by spectroscopy and the lifetime of the dressed atoms reaches several minutes. The oscillation frequencies are measured for different values of the RF field and magnetic gradient, indicating the achievement of a highly anisotropic trap. For the maximum value of the magnetic gradient, we reach the two-dimensional regime for the degenerate gas.
Our results represent an important step towards the realization of a ring-shape trap[2] where we will investigate the connection between superfluidity and Bose-Einstein condensation in 2D and 3D.

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Quantitative study of Conductance Fluctuation in Epitaxial Bi_2Se_3

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Three-dimensional topological insulators (TI) are exotic matters that have spin-polarized Dirac electrons on the surface state with a finite band gap in the bulk state. In order to address some exotic properties of the Dirac electrons, it is of primary necessity to experimentally investigate quantum transport phenomena of TI such as conductance fluctuation. However there are only a few reports about the conductance fluctuation in TI [1,2,3] although the origin of the conductance fluctuation is still not obvious.
In this presentation, we report conductance fluctuation in 100 nm-width wires fabricated from epitaxial Bi2Se3 thin film. We measured wires whose lengths are from 2 µm to 15 µm in order to investigate the fluctuation dependence on the wire length.

The conductance fluctuation decreases as the wire length becomes longer and the dependence is well described by a ratio of the coherence length to the wire length. Additionally, the sizes of the conductance fluctuation approach near the universal value, e^2/h, when the electrons remain the phase coherence around the whole region of the wires. This result is a strong evidence that an origin of the fluctuation is the universal conductance fluctuation.

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[3] J. G. Checkelsky *et al.*, Phys. Rev. Lett. **103**, 246601 (2009

Réponse dynamique d'un nanoconducteur : l'exemple du circuit RC quantique

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Interagir et contrôler les électrons en temps réel constitue un des principaux défis auxquels sont confrontés les expériences de transport dans les boîtes quantiques. Le circuit RC quantique est un exemple typique d'expérience dans le domaine des hautes fréquences, son comportement étant dicté à la fois par des effets de cohérence quantique et par les corrélations induites par les fortes interactions électroniques en milieu confiné.
Ce circuit est l'analogue quantique du circuit RC classique : il comprend une boîte quantique couplée capacitivement à une grille proche et connectée à un réservoir monocanal par l'intermédiaire d'un point de contact quantique.
Dans ce travail, nous expliquons l'apparition, pour ce circuit, d'une résistance quantifiée [1] à basse température, indépendante de la transmission vers le réservoir. L'origine physique de cette quantification est expliquée à l'aide d'une approche de liquide de Fermi [3].
Dans le cas où la boîte quantique est décrite par le modèle d'Anderson, nous montrons [2] l'émergence d'un pic dans la résistance AC en fonction du champ magnétique.

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A 4-point cross-correlation voltage noise set-up for investigating the Shot Noise of ballistic Graphene nano-constrictions

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In the ideal graphene nano-ribbon, it has been theoretically predicted that the Fano factor of shot noise reaches its maximum ~1/3 at the Dirac point. In our experiment, we aim to verify this statement doing cross-correlation noise measurements. To ensure that we are not sensitive to the quality of the contacts and that we probe a ballistic part of the graphene flake, we designed our sample to realize a four point noise measurement. To perform this experiment, cryogenic amplifiers were developed, characterized and calibrated by measuring the noise (Johnson-Nyquist noise and shot noise) of a quantum point contact in GaAs/GaAlAs heterostructure. For the sample fabrication, we first obtained a graphene flake using exfoliation method, then metallic contacts and gates were designed using standard e-beam lithography technique, and in a final step a constriction was etched applying O_2 plasma. We will present the noise performance of the set-up as well as preliminary measurements.

Magnetic impurity on the surface of a strong topological insulator

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Implementation of a Tunable High-Impedance Microwave Environnement

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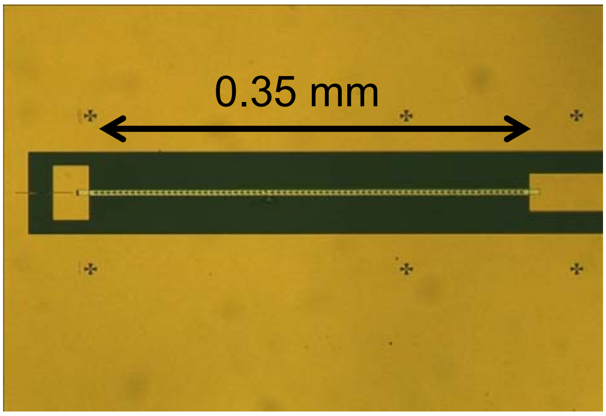
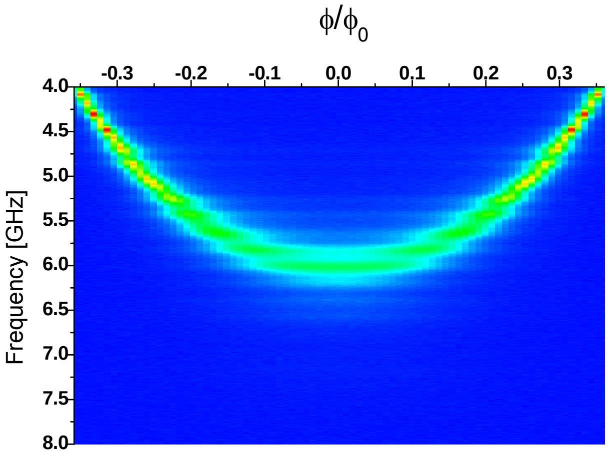
Probing mesoscopic systems at high frequencies allows to access new phenomena, where the quantization of electromagnetic energy plays an important role. Detecting these phenomena requires that the energy of a photon at the experiment's frequency is significantly higher that the thermal energy, which in practice imposes to work in the GHz range. This brings a new technical difficulty: the mismatch between the 50 Ω impedance of commercial microwave components and the resistance quantum (25.9 kΩ), which is the natural scale for the impedance of most quantum conductors. This difficulty is circumvented by implementing impedance matching resonator, which improves the efficiency of coupling at the expense its bandwidth. In this work we have improved the coupling-bandwidth product by building a high impedance transformer based on a Josephson junction meta-material. More specifically, the device consists in a quarter-wavelength resonator whose inner conductor is made of a serial SQUID array. This allows us to take advantage of the Josephson inductance, increasing the characteristic impedance of the transformer to a few kilo-Ohms. Moreover, the SQUID geometry allows in-situ tuning of the resonator's frequency and characteristic impedance. We have achieved matching to a 30 kΩ impedance over a 400 MHz bandwidth centered at 6 GHz, with a tunability from 4 to 6 GHz.





Superconducting order and spin-orbit competition on graphene.

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Two-dimensional topological insulators are commonly referred to as quantum spin-Hall (QSH) states [1].
Contrary to the three-dimensional topological insulators that have been found to abound in nature, the two-dimensional are rather limited. However recently a spin-orbit induced QSH phase has been proposed [2]. The key ingredient is the use of indium adatoms deposited on the surface of graphene thats should turn the latter into a QSH insulator characterized by a sizable gap. This artificial QSH system present strong potentials applications for thermopower [3] or spintronics [4] devices.
One interesting fact about indiums is that the latter becomes superconductor at low enough temperature,
Therefore the graphene+indium artificial QSH system becomes a promising candidate to study the competition between induced superconductivity and the spin-orbit coupling. This preliminary work pave the way of this survey. We show that starting form a general superconducing plaquette interaction, the latter can be reduced to a simpler effective model that includes only one-site and nearest neighbors interactions. This permit us to determine the first preliminary phase diagram.

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Single molecule detection of nanomechanical motion

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We investigate theoretically how well-established single-molecule spectroscopy techniques [1,2] can be used to perform fast and high resolution displacement detection of nanomechanical oscillators, such as singly clamped carbon nanotubes. Depending on the ratio between the mechanical oscillator frequency and the luminescence linewidth, the spectroscopic signal can be used to obtain either the oscillator real time displacement (slow oscillator) or its mean square fluctuation (fast oscillator). In the fast oscillator limit we find that an interference pattern appears in the degree of second order coherence function of the molecular luminescence. Our estimates show that not only the proposed measurements can be realized with the existing level of technology, but one may be also able to study strong back action effects, such as the back action cooling [3].

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[3] V. Puller, B. Lounis, and F. Pistolesi, Single molecule detection of nanomechanical motion, to be published

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Andreev current induced by ferromagnetic resonance

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We study charge transport through a metallic dot coupled to a superconducting and a ferromagnetic lead with a precessing magnetization due to ferromagnetic resonance. Using the quasiclassical theory, we find that the magnetization precession induces a dc current in the subgap regime even in the absence of a bias voltage. This effect is due to the rectification of the ac spin currents at the interface with the ferromagnet; it exists in the absence of spin current in the superconductor. When the dot is strongly coupled to the superconductor, we find a strong enhancement in a wide range of parameters as compared to the induced current in the normal state.

On-chip Photon-assisted detection of the noise of a Quantum Point Contact

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We describe the first experimental realization of on-chip detection of the noise of a Quantum Point Contact (QPC) (emitter) using an additional capacitive-coupled QPC (detector). Here, the QPC emitter is dc biased and emits a wide band quantum shot noise which, due to the capacitive coupling, will generate electron-hole pairs in the detector line. The detection is based on the following mechanism: when a QPC is submitted to a time dependent drain-source voltage, electron-hole pairs are generated. Their partitioning at the QPC generates a current noise called photon-assisted shot noise (PASN). Alternatively to shot noise, electron-hole pairs also generate a photon-current. We report photo-current and PASN measurements in excellent agreement with theoretical predictions. In particular, this approach enables us to detect fluctuations up to several tens of GHz and could be extended to THz by improving the geometry or replacing QPCs by carbone nanotubes.

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[1] Y. Jompol, Th. Jullien, P. Roulleau, I. Farrer, D.A. Ritchie, and D.C. Glattli in preparation. .

Superconducting nanostructures with thermally evaporated Niobium

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Conventional lithography of superconducting nanodevices using Nb generaly suffers from contamination issues, due to degassing of the organic resist facing the extremely hot Nb target. The devices usually display a strongly reduced, when not vanishing, critical temperature Tc. We present a novel lithographic method based on the use of a metallic rather than organic lithography mask. Using an Al/Mo bilayer mask, we routinely produce narrow (300 nm) and long Nb lines with a Tc as high as 7-8 K. We further demonstrate the fabrication of Nb/Au/Nb proximity SQUIDS. It is finally shown that beyond preserving Tc, the technique presented is well suited for connecting graphene and for scanning probe-inspection of the devices.

Ecrantage dynamique lors de la formation d'une lacune dans un ruban de graphene: effet du spin-orbite

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Le découplage d'un atome d'un ruban de graphene est étudié en fonction de la vitesse d'éjection de l'atome. Le ruban de graphene est modélisé avec l'Hamiltonian de Kane et Mele. Des effets nonadiabatiques apparaissent quand la vitesse est grande. Ces effets sont étudiés en fonction de la position de l'atome éjection dans le ruban. La dépendance avec le couplage spin-orbite est examinée. .

Tunneling spectroscopy study of graphene on superconducting Rhenium

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The induced superconducting proximity effect in graphene can be achieved with different sample designs. The one explored here is the chemical vapor deposition (CVD) growth of graphene on top of a superconductor, Rhenium in our case.
High quality epitaxial Rhenium thin films were prepared in ultra-high vacuum (UHV) by electron beam evaporation onto polished single-crystal sapphire substrates. Then the sample was transferred to a second UHV system equipped for the graphene CVD growth. STM studies reveal large flat terraces fully covered with graphene and the existence of a moiré superstructure of 2-2.5nm periodicity, which is typical of graphene on lattice mismatched substrates [1]. Atomic resolution STM images were also performed on the moiré pattern.

Very low temperature STM spectroscopy measurements on graphene grown on Rhenium display a very homogeneous superconducting state below a superconducting transition temperature $T_c \geq 2K$, significantly higher than the critical temperature of bare Rhenium films. Slight differences in the density of states seem to be found at different corrugation heights of the moiré, which needs to be confirmed by forthcoming experiments. Under a perpendicular magnetic field of a few hundred Gauss, a disordered array of vortices has been observed and the electronic density of states of the vortex core has been obtained.

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Correlation and interaction effect between few electrons in a doped silicon nanowire

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Through resonant tunnelling transport experiments in doped silicon nanowires we identify the ionization of few implanted shallow donors. The ionization energy for each donor depends on its position in the nanowire –with respect to the buried oxide, gates and source/drain contacts- as well as on the position and ionization of others donors [1].
Our system is a model system where electrons are put one-by-one in a disorder potential. We have evidenced two important carrier's interaction effects in our samples:
First we show that Coulomb repulsion between electrons located on distant donors regularize the addition spectrum for electrons in the channel as a precursor for the formation of a large band tail in the conduction band [2].
Second we observe the Fermi edge singularity effect – an increase of the current when an electron tunnels at the Fermi energy between a donor and the drain electrode [3]. This effect is particularly important in our samples because the direct Coulomb interaction between an ionized donor in the channel and the electrons in the drain electrode is strong.

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Effect of Coulomb interaction on two electron interferences in the nu=2 quantum Hall effect

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Emitting a single electron at a time is of great importance in order to study electronic interferences as elementary processes. This has been achieved experimentally in the quantum Hall effect at filling factor nu=2 but recent results have shown that electronic interactions are not negligible in such a setup. Consequently, we consider a quantum Hall bar at this filling factor where interaction is turned on between the co-propagating channels on each edge. We inject single electrons on both incoming edges as exponential wave packets in real space which can backscatter at a quantum point contact, therefore mimicking the quantum optics Hong-Ou- Mandel interferometer. Because of interaction, the charge is fractionalized into two components propagating with different velocities. When computing the zero-frequency current correlations, we observe several dips whose depth and shape depend on the nature of the excitations interfering and on the interaction strength. .

Giant current noise in nanoelectromechanical systems close to mechanical instabilities

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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. 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.

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Massless Dirac bosons in honeycomb plasmonic lattices

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

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