Moriond2011 Quantum Mesoscopic Physics

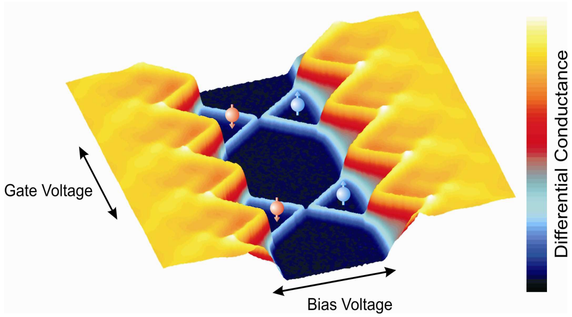
La thuile 13-20 March 2011

Sunday 13 March 2011

From 15h00	Registration	
19h00	Welcome cocktail	
20h00	Dinner	
		Monday 14 March 2011
9h00	**Glattli & Sanquer**	**Opening Moriond 2011 "Quantum Mesoscopic Physics"**
		Mesoscopic transport in Graphene and Carbone Nanotubes, and topological insulators
9h10	**Ph. Kim**	**Interaction in graphene.**
10h00	**A. Morpurgo**	**Normal and Superconducting transport through a gated topological insulator** I discuss our recent transport experiments on thin crystalline layers of Bi2Se3 ?currently the best representative of 3D toplogical insulators- produced using techniques borrowed from the field of graphene electronics. The experiments rely on the measurement of magneto transport through devices equipped with a gate, which enable the observation of the fan diagram of Landau levels and the unambiguous identifications (and controlled filling) of surface Dirac electron and holes. At low-temperature and zero magnetic field, the use of superconducting electrodes allows the observation of supercurrent flowing through the system. The supercurrent is also found to be gate-tunable, indicating that at least a fraction of it is carried by Dirac fermions. Our results provide clear evidence that the Dirac surface states are robust and survive in the presence of considerable disorder, i.e. they provide indications as to the important role of topological protection.
10h30	Coffee	
11h00	**P. Silvestrov**	**Pseudo-Helical Surface States in Topological Insulators** P.G.Silvestrov1, E.G.Mishchenko2, P.W.Brouwer1.1Freie Universitaet Berlin, Germany 2 University of Utah, USA The spin of surface states of a 3d topological insulator (similar to the recently discovered materials like Bi2Se3) is investigated theoretically. Although the surface states demonstrate a nontrivial spin-structure, the expectation value of spin is suppressed, or in the simplest models even become zero. This happens because of cancellation of contributions coming from two sublattices of the crystal. Possible consequences of our results for spin-resolved ARPES measurements are discussed. Charging of the topological insulator surfaces caused by the anisotropy of the Hamiltonian is also considered.

11h20	**T. Ihn**	**Electronic Transport in Graphene Nanostructures** Quantum constrictions and quantum dots made of graphene do not easily reproduce the well-known effects of conductance quantization and Coulomb-blockade physics known from semiconductor field-effect devices. The role that states at edges, their degree of localization, bulk disorder, and the graphene-specific band structure play is currently under intense investigation. We have performed extensive transport experiments on single-and bilayer nanoribbons, and single- and double- quantum dots addressing these issues. In addition, using the scanning tip of an atomic force microscope at low temperatures, we have been able to locate resonant states in the constrictions connecting a quantum dot to source and drain, and to study their influence on electronic transport and their interactions with quantum dots states [1]. It is evident from our measurements, that Coulomb interactions play a major role in the physics of graphene constrictions. [1] S. Schnez et al., Phys. Rev. B 82, 165445 (2010).
11h50	**J.-N. Fuchs**	**Topological Berry phase and semiclassical quantization of cyclotron orbits for 2D electrons in coupled band models** The semiclassical quantization of cyclotron orbits for two-dimensional Bloch electrons in a coupled two band model with a particle-hole symmetric spectrum is considered. As concrete examples, we study graphene (both mono and bilayer) and boron nitride (also known as "gapped graphene"). The main focus is on wave effects -- such as Berry phase and Maslov index -- occurring at order hbar in the semiclassical quantization and producing non-trivial shifts in the resulting Landau levels. Specifically, we show that the index shift appearing in the Landau levels is related to a topological part of the Berry phase -- which is basically a winding number of the direction of the pseudo-spin 1/2 associated to the coupled bands -- acquired by an electron during a cyclotron orbit and not to the complete Berry phase, as commonly stated. As a consequence, the Landau levels of a coupled band insulator are shifted as compared to a usual band insulator. We also study in detail the Berry curvature in the whole Brillouin zone on a specific example (boron nitride) and show that its computation requires care in defining the "k-dependent Hamiltonian" H(k), where k is the Bloch wavevector.
12h20	Lunch	
		Mesoscopics of hybrid systems: superconducting/ferro/Normal/Kondo
17h00	**A. Cottet**	**A spin quantum bit with ferromagnetic contacts for circuit QED** We theoretically propose a scheme for a spin quantum bit based on a double quantum dot contacted to ferromagnetic elements [1]. Interface exchange effects enable an all electric manipulation of the spin and a switchable strong coupling to the photons confined in a superconducting coplanar waveguide cavity. This allows to envision on-chip single spin manipulation and readout using cavity QED techniques. Our setup does not rely on any specific band structure and can in principle be realized with many different types of nanoconductors. We discuss in particular the case of an implementation with carbon nanotubes. [1] A. Cottet and T. Kontos, Phys. Rev. Lett. 105, 160502 (2010)

17h20	**Y. Avishai**	**Spin-orbit effects in one dimensional metallic wires** Two systems exhibiting spin-orbit effects in one dimensional wires will be discussed: {\bf I. Purely electric spin pumping along a metallic wire }: (Phys. Rev. Lett. {\bf 104}, 196601 (2010)). A simple one dimensional system (such as metallic wire) can display quantum spin pumping possibly without pushing any charge. It is achieved by applying two slowly varying orthogonal gate electric fields on different sections of the wire, thereby generating local spin-orbit (Rashba) terms such that unitary transformations at different places do not commute. This construction is a unique manifestation of a spin-orbit observable effect in purely one dimensional systems with potentials respecting time-reversal symmetry. {\bf II. Magnetization of two touching rings} (Journal of Physics A (Math Theor.) {\bf 42}, 175301 (24pp) (2009)). The Magnetization of a mesoscopic system consisting of two clean metallic rings sharing a single contact point, and subject to magnetic and electric fields is studied and computed. Spin-orbit interactions, induced by the electric fields of charged wires threading the rings, give rise to a peculiar version of the Aharonov-Casher effect where, unlike for a single ring, spin is not conserved. Remarkably, this can only be realized when the Aharonov-Bohm fluxes in both rings are neither integer nor half-integer multiples of the flux quantum. where unlike for a single ring, spin is not conserved. Remarkably, this can only be realized when the Aharonov-Bohm fluxes in both rings are neither integer nor half-integer multiples of the flux quantum.
17h40	**Y. Nazarov**	**Topological properties of superconducting junctions** Motivated by recent developments in "topological" superconductors, we study topological properties of s-matrix of superconducting junctions. We argue that for a finite junction the s-matrix is always topologically trivial. Apparent contradiction with previous research is resolved if low-energy resonant poles of s-matrix are taken into account. This suggests that for finite junction a common topological transition does not take place. Instead, we reveal a different topological transition that concerns the configuration of the resonant poles.
18h10	Coffee	
18h40	**S. Valenzuela**	**Experimental realization of a single-electron spin ratchet** We describe a spin ratchet at the single-electron level that produces spin currents with no net bias or charge transport [1]. Our device is based on the ground-state energetics of a single-electron transistor comprising a superconducting island connected to normal leads via tunnel barriers with different resistances that break spatial symmetry. We demonstrate spin transport and quantify the spin ratchet efficiency by using ferromagnetic leads with known spin polarization. [1] M.V. Costache and S.O. Valenzuela, Science 330, 1645 (2010)

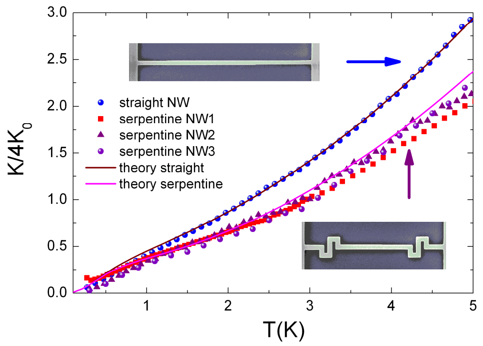


19h10	**V. Shumeiko**	**Nonadiabatic Josephson dynamics in junctions with in-gap quasiparticles** Conventional models of Josephson junction dynamics rely on the absence of low-energy quasiparticle states owing to a large superconducting energy gap. With this assumption the quasiparticle degrees of freedom are frozen out, and the phase difference becomes the only free variable, acting as a fictitious particle in a localized Josephson potential related to the adiabatic and nondissipative supercurrent across the junction. We develop a general framework to incorporate the effects of low-energy quasiparticles interacting nonadiabatically with the phase degree of freedom. These quasiparticle states typically exist in mesoscopic junctions with high transparency conducting channels or resonant states, as well as junctions of unconventional superconductors. Recent experiments have also revealed the existence of spurious low-energy in-gap two-level systems in macroscopic tunnel junctions of conventional superconductors, for which the adiabatic assumption is typically assumed to be valid. We show that a resonant interaction with low-energy bound states, rather than confinement by the Josephson potential, determines the nonlinear Josephson dynamics at small amplitudes. We also discuss the effect of low-energy bound states in d-wave junctions on macroscopic quantum tunneling. J. Michelsen and V. S. Shumeiko Phys. Rev. Lett. 105, 127001 (2010); Low Temp. Phys. 36, 925 (2010)
19h30		
20h00	Dinner	
21h00	**Poster session 1**	
		Tuesday 15 March 2011
		Quantum dynamics, High frequency and time dependent phenomena, charge manipulation, quantum shot noise and full counting statistics
9h	**L. Kouwenhoven**	**Quantum Opto-Electronics in Semiconductor Nanowires**
9h50	**G. Blatter**	**Quantum counting in mesoscopic systems** During past years, substantial effort has been put into the statistical analysis of transport in mesoscopic systems through the calculation of the full counting statistics of the process. In quantum counting, we deal with the next step in this program, the precise counting of passing particles in a non-demolition measurement. Analyzing a minimal formulation of the counting task in terms of the problem of distinguishing between different known quantum states in a single-shot measurement (unary counting), we find that non-demolitian quantum counting is naturally related with the operation of quantum Fourier transformation. We discuss a quantum counting algorithm with qubits providing a binary representation of the number of passed particles and a test for the divisibility of this number by powers of 2--the algorithm can be generalized to base-d counting and a divisibility test by powers of d using qudits, d-level quantum systems. We discuss the relation to the phase estimation algorithm and applications in the generation of multi-particle entanglement and in quantum metrology, specifically voltage measurement.
10h20	Coffee	

10h50	**K. Kobayashi**	**Nonequilibrium Fluctuation Relations in a Quantum Coherent Conductor** The fluctuation-dissipation relation tells that the response of a physical system to an external force is proportional to its equilibrium fluctuation. In electrical circuits this fact manifests itself as the Johnson-Nyquist relation in such a way that the conduction through a conductor is proportional to its current noise in equilibrium. However, such a treatment is justified only when the systems are close to the equilibrium. Here we demonstrate nonequilibrium fluctuation relations in a quantum coherent regime; beyond the Johnson-Nyquist relation we have found higher-order (in applied voltage) correlations between the current and the current noise of the voltage-biased mesoscopic conductor. The present non-equilibrium relation, being asymmetric in magnetic field unlike the Onsager-Casimir symmetry, is valid even in the presence of interactions. The demonstrated direct link between non-linearity in voltage and fluctuations out-of-equilibrium, which has been discussed only theoretically [1-3], provides for the first time the experimental evidence of the fluctuation theorem [4] in the quantum coherent regime in the presence of the magnetic fields and thus opens up a new way to explore non-equilibrium statistical mechanics [5]. [1]J. Tobiska and Yu. V. Nazarov, Phys. Rev. B 72, 235328 (2005). [2]K. Saito and Y. Utsumi, Phys. Rev. B 78, 115429 (2008). [3]H. F?rster and M. B?ttiker, Phys. Rev. Lett. 101, 136805 (2008). [4]D. J. Evans, E. G. D. Cohen, and G. P. Morriss, Phys. Rev. Lett. 71, 2401 (1993). [5]S. Nakamura, Y. Yamauchi, M. Hashisaka, K. Chida, K. Kobayashi, T. Ono, R. Leturcq, K. Ensslin, K. Saito, Y. Utsumi, and A. C. Gossard, Phys. Rev. Lett. 104, 080602 (2010).
11h10	**D. Ivanov**	**Phase transitions in full counting statistics for periodic pumping** We discuss the problem of full counting statistics for periodic pumping. The probability generating function is usually defined on a circle of the "physical" values of the counting parameter, with its periodicity corresponding to charge quantization. The extensive part of the generating function can either be an analytic function on this circle or have singularities. These two cases may be interpreted as different thermodynamic phases in time domain. We discuss several examples of phase transitions between these phases for classical and quantum systems. Finally, we prove a criterion for the "analytic" phase in the problem of a quantum pump for noninteracting fermions.
11h30	**P. Roche**	**High frequency quantum noise: the statistics of photons emitted by electronic shot noise in a normal tunnel junction** What is the statistics of microwave photons radiated by the current fluctuations of a quantum conductor? When the conductor is at equilibrium at temperature T, the statistics is that of a black body radiation. However little is known about the statistics of the photons emitted in the non-equilibrium case where the conductor is biased by a voltage V >> kBT/e and the current fluctuations are due to quantum shot noise. An intriguing question is the link between the statistics of electrons and that of the emitted photons. This problem has recently attracted theoretical interest and the full range of photon statistics, from chaotic to non-classical, has been predicted [1,2]. The result depends on the competition between the fermionic and bosonic statistics of electrons and photons respectively. More generally, this rich physics relates to the problem of the electron Full Counting Statistics, as the second moment of the photon noise directly links to a fourth-moment of the current fluctuations [2]. In this talk, I will present measurements of the statistics of photons radiated by a quantum conductor in the shot noise regime [3]. Our experimental method based on Hanbury-Brown Twiss (HBT) microwave photon correlation. For the simplest quantum conductor studied here, a tunnel junction, although the statistics of electrons crossing the conductor is Poissonian, the photon statistics is shown to be chaotic. This is found even in the regime of vanishing electron shot noise where the voltage is close to the photon energy (eV ~ hn),so that the photon population is small, in agreement with the predictions of [1]. [1] C. W. J. Beenakker and H. Schomerus, Phys. Rev. Lett.86, 700 (2001), Phys. Rev. Lett. 93, 096801 (2004) ; I.C. Fulga, F. Hassler, C.W.J. Beenakker, Phys. Rev. B 81, 115331 (2010) [2] A. V. Lebedev, G. B. Lesovik, and G. Blatter, Phys. Rev. B 81, 155421 (2010). [3] E. Zakka-Bajjani et al., Phys. Rev. Lett. 104, 206802 (2010)

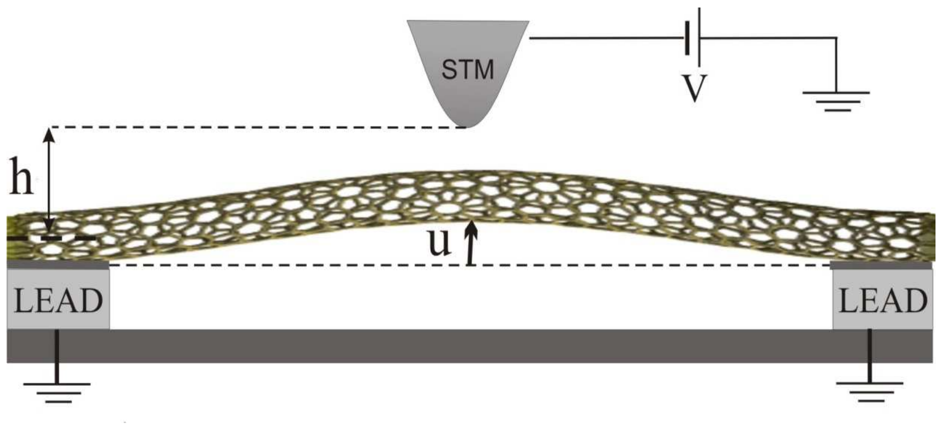
12h00	**R. Deblock**	**Emission and Absorption Quantum Noise Measurement with an On-Chip Resonant Circuit** Using a quantum detector, a superconductor-insulator-superconductor junction, we probe separately the emission and absorption noise in the quantum regime of a superconducting resonant circuit at equilibrium. At low temperature the resonant circuit exhibits only absorption noise related to zero point fluctuations, whereas at higher temperature emission noise is also present. By coupling a Josephson junction, biased above the superconducting gap, to the same resonant circuit, we directly measure the noise power of quasiparticles tunneling through the junction at two resonance frequencies. It exhibits a strong frequency dependence, consistent with theoretical predictions. We discuss how this technique allows to probe the high frequency noise associated with the Kondo effect in carbon nanotube. Reference : J. Basset, H. Bouchiat and R. Deblock, Phys. Rev. Lett. 105, 166801 (2010).
12h20	Lunch	
		Mesoscopics of hybrid systems: Disordered superconductors and metals.
16h30	**M. Feigelman**	**Superconductor-Insulator transition and energy localization**
16h50	**Y. Meir**	**New formulation of transport through low dimensional disordered superconductors** A new formulation of calculating the current through superconductors connected to metallic reservoirs, which includes phase fluctuations, is developed. Beyond confirming well known results when applied to simple geometries, this formalism is applied to several experimental setups which led to some puzzling results, such as thin superconducting cylinders that exhibit a normal phase upon application of flux, nonmonotonic temperature dependence of the resistance, or the huge magnetoresistance peak observe in thin films.
17h20	**C. Chapelier**	**Scanning tunneling spectroscopy and Andreev spectroscopy of highly disordered superconducting films** We have performed tunneling spectroscopy and point-contact Andreev spectroscopy on disordered superconducting indium oxide films. These samples are in the vicinity of the metal-insulator Anderson transition. Tunneling spectroscopy highlights a rather unusual superconducting state with a pseudogap regime above the critical temperature. It evolves at low temperature into an inhomogeneous system composed of both superconducting Cooper pairs and localized Cooper pairs without phase coherence [1]. Besides, using our STM, we have continuously analyzed the local conductance between the tunneling regime and the point-contact regime. In the latter, Andreev spectroscopy reveals a new energy scale related to the quantum coherence energy and independent from spatial fluctuations of the pairing energy [2]. [1] B. Sacépé et al., to be published in Nature Physics. [2] T. Dubouchet et al., in preparation.
17h50	**M. Gershenson**	**Magnetic-field-driven phase transitions in Josephson arrays.** We have studied the phase transitions induced by the magnetic field B in arrays of small Josephson junctions. The number of nearest-neighbor junctions connected to a single superconducting island varied between 4 and 11 for different arrays. When frustrated by the magnetic field, the arrays demonstrated several quantum phase transitions at different critical values of the resistance R=3-10 kOhm, which is in line with earlier observations. In particular, with increasing B we observed transitions between three states: a) the superconducting state with zero R, b) the ?metallic? state with the weakly-T-dependent R at 40mK(19/01/2011)

18h10	**J-J. Lin**	**Time-dependent universal conductance fluctuations in metal oxide nanowires due to mobile defects** Time-dependent universal conductance fluctuations (UCF) are observed in RuO_2 nanowires at cryogenic temperatures. The fluctuations persist up to unprecedentedly high temperatures of ~10 K. Their root-mean-square magnitudes increase with decreasing temperature, reaching approximately 0.2e^2/h, the quantum conductance, at temperatures below ~2 K. These fluctuations are shown to originate from scattering of conduction electrons with rich amounts of mobile defects in artificially synthesized metal oxide nanowires. Furthermore, UCF characteristics in both one-dimensional saturated and unsaturated regimes are identified, in quantitative consistency with earlier theoretical predictions [S. Feng, in "Mesoscopic Phenomena in Solids", ed. by B. L. Altshuler, P. A. Lee and R. A. Webb (1991)]. In another case of IrO_2 nanowires where the mobile defects are less pronounced, UCF as a function of varying magnetic fields are clearly observed.
18h30	Coffee	
		Cold Atoms
19h00	**W. Zwerger**	**Many-Body Physics with Ultracold Atoms**
19h50	Dinner	
		Wednesday 16 March 2011
		Mesoscopic thermodynamic effects, thermal transport, meso-optomechanics.
9h00	**J. Pekola**	**Coupling of electrical circuits to photon, phonon and electron environments**
9h50	**O. Bourgeois**	**Blocking the phonon thermal transport in at the nanoscale** We report the measurement of thermal conductance of suspended silicon nanowires (section 200nm by 100nm and 10?m long) at low temperature. They have been measured using the 3-omega method between 0.3K and 6K (Fig.1). We have evidenced the existence of a specific regime for the transport of phonons at low temperature. It is revealed by the non-trivial temperature dependence of the thermal conductance signature of a mix between ballistic and diffusive transport. This transport is governed by the competition between the mean value of the roughness and the dominant phonon wavelength. The thermalization of the phonon on the surfaces is strongly modified at the nanoscale by the specular reflection implying an increase of the phonon mean free path. To illustrate that we measured also nanowires having a serpentine nanostructure evidencing that changes in geometrical shape can strongly affect heat flow. By engineering serpentine shaped nanowires, the phonon transmission is reduced by nearly 40% at temperatures below 5K [1] (see fig. 1 (the curves in purple, pink and red)) as compared to the straight nanowires (in blue). The measurement between the two types of nanowires can be compared because they have the same length (10µm). This amount of reduction is strikingly large demonstrating the blocking of the ballistic phonon transport. We have performed a detailed transmission function analysis going beyond a simple Ziman model. It yields a very satisfactory agreement with experimental measurements (see fig. 1). [1] J-S. Heron, C. Bera, T. Fournier, N. Mingo, and O. Bourgeois, Phys. Rev. B 82, 155458 (2010).



10h10	**F. Pistolesi**	**Euler buckling instability and enhanced current blockade in suspended single-electron transistors** Single-electron transistors embedded in a suspended nanobeam or carbon nanotube may exhibit effects originating from the coupling of the electronic degrees of freedom to the mechanical oscillations of the suspended structure. Here, we investigate theoretically the consequences of a capacitive electromechanical interaction when the supporting beam is brought close to the Euler buckling instability by a lateral compressive strain. Our central result is that the low-bias current blockade, originating from the electromechanical coupling for the classical resonator, is strongly enhanced near the Euler instability. We predict that the bias voltage below which transport is blocked increases by orders of magnitude for typical parameters. This mechanism may make the otherwise elusive classical current blockade experimentally observable. References: [1] G. Weick, F. Pistolesi, E. Mariani, and F. von Oppen Physical Review B (Rapid Communication) 81, 121409(R) (2010) [2] G. Weick, F. von Oppen, and F. Pistolesi, Phys. Rev. B (in press).
10h30	Coffee	
11h00	**H. Courtois**	**Electronic cooling in superconductor-based tunnel junctions: basics and fundamental limitations** L. Pascal, S. Rajauria, H. Q. Nguyen, P. Gandit, B. Pannetier, F. Hekking, C. Winkelmann and H. Courtois Electronic cooling in a Superconductor - Insulator - Normal metal (S-I-N) junction arises from the energy selectivity of electron tunneling induced by the superconductor energy gap. The efficiency of coolers based on a pair of such junctions is usually significantly less than theoretically expected. After introducing the basic principles at the heart of superconducting micro-coolers, I will review the fundamental limitations to electronic cooling. A thermal model including electron-phonon coupling and Kapitza resistances enables us to estimate electron as well as phonon cooling. In junctions with an significant tunnel transparency, two-particle Andreev current brings a fully efficient heat contribution that competes with cooling based on single particle tunneling [1]. In the superconductor, a large number of out-of-equilibrium quasi-particles are injected, that diffuse and recombine only slowly in the superconductor. We have elaborated a model for quasi-particle diffusion, trapping and back-tunneling that enables us to fit our experimental data and gives valuable information on practical coolers optimization [2]. Eventually, photonic heat related to the thermal noise arising in the circuit resistors can bring an additional heat contribution, depending on the transmission of the biaising circuit [3]. [1] S. Rajauria, P. Gandit, T. Fournier, F. W. J. Hekking, B. Pannetier, and H. Courtois. Andreev Current-Induced Dissipation in a Hybrid Superconducting Tunnel Junction. PRL 100, 207002 (2008) [2] S. Rajauria, H. Courtois and B. Pannetier, Quasiparticle-diffusion-based heating in superconductor tunneling microcoolers. Phys. Rev. B 80, 214521 (2009). [3] L. Pascal, H. Courtois, and F. W. J. Hekking. Circuit approach of photonic heat transport. arxiv.org/1003.3217.

11h20	**N. Didier**	**Detecting phonon blockade with photons** Measuring the quantum dynamics of a mechanical system, when few phonons are involved, remains a challenge. We show that a superconducting microwave resonator linearly coupled to the mechanical mode constitutes a very powerful probe for this scope. This new coupling can be much stronger than the usual radiation pressure interaction by adjusting a gate voltage. We focus on the detection of phonon blockade, showing that it can be observed by measuring the statistics of the light in the cavity. The underlying reason is the formation of an entangled state between the two resonators. Our scheme thus realizes a phonotonic Josephson junction and, moreover, it offers a way to prepare and detect entangled states between phonons and photons. N. Didier, S. Pugnetti, Y. M. Blanter, and R. Fazio, arXiv:1007.4714
11H40	**L. Gorelik**	**DC Excitation and Cooling of the Carbon Nanotubes Vibrations.** We have theoretically investigate an electromechanical properties of a freely suspended carbon nanotube when a dc-current is injected into the tubes using a scanning tunneling microscope. We demonstrate that the quantum interplay between two mechanisms for coupling the electronic and mechanical subsystems results in a bias voltage dependent difference between the probability amplitudes for vibron emission and absorption during electronic tunneling. For a bias voltage above Coulomb blockade threshold we find that interference has constructive character for the transitions with vibron emission and destructive for the transitions with vibron absorption. As a result shuttle-like electromechanical instability occurs if the bias voltage exceeds a dissipation-dependent threshold value. Below Coulomb blockade threshold we find that the vibron absorption dominates. As a result, thermally activated electronic transport through the system leads to an effective cooling of the nanotube vibration. In order to analyze this phenomena we derive a master equation for the reduced density matrix and show that such cooling is possible down to a ground state level where the average vibron population of the fundamental bending mode is 0.2.



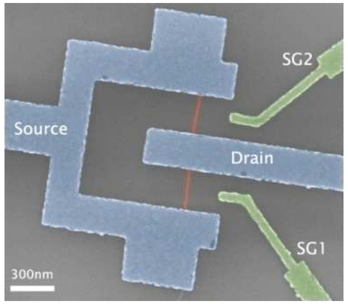
12h00 **M. Sillanpää** **Electromechanically induced microwave amplification**

An on-chip microwave resonator can be capacitively coupled to a nanomechanical resonator, similarly as in an optical cavity with a movable end mirror. In the dispersive limit where the LC ("cavity") frequency is much higher than the mechanical frequency which usually is in the radio-frequency regime, the mechanical motion couples to the electrical frequency. We investigate such a system, where a 7 GHz cavity is capacitively coupled to a 30 MHz flexural beam resonator via an ultranarrow 15 nm vacuum gap. The cavity is strongly driven by a "pump" microwave at the blue sideband above the cavity resonance. Under certain pump conditions, we observe mechanical amplification of another, probe, signal applied at the cavity frequency by up to 30 dB. To our knowledge, this constitutes the first implementation of a mechanical microwave amplifier with true power gain. The decrease in the absorption at the cavity frequency can be thought of as an analog of the electromagnetically induced transparency in quantum optics. In the opposite operation mode, where the cavity is irradiated at the red sideband, we observe cooling starting from the initial thermal population of 20 phonons. We develop a full quantum theory for the mechanical amplification, and obtain a good agreement to the experiment. We discuss the prospects to obtain quantum-limited microwave amplification when the thermal population of the mechanical resonator would approach zero.

12h20 Lunch

Mesoscopic transport in Graphene and Carbone Nanotubes

17h00 **R. Maurand** **Experimental 0-π phase diagram of a carbon nanotube Josephson junction obtained in a nano-SQUID.**



A single wall carbon nanotube (SWNT) in a resonant tunneling conduction regime between two superconductors realizes a hybrid Josephson quantum dot (QD) junction. Indeed, in a transistor-like configuration, it is possible to tune the critical current of the Josephson junction with the gate. This new class of Josephson junctions provides both reduced dimensions along with a new control access of the critical current. Moreover, such a junction exhibits two manifestations of electronic correlations: Kondo effect and superconductivity. The interplay between these two competing phenomena can give rise to peculiar properties such as a p-dephasing of the current-phase relation of the Josephson junction : the so-called p-junction [van Dam, Cleuziou]. In this work, we focus on the 0-p transition of SWNT-based Josephson QD junctions. For this purpose, we have built a Superconducting Quantum Interference Device (SQUID), the weak links of which are realized by two portions of the same SWNT [Cleuziou]. Such geometry allows measuring directly the p-dephasing in the magnetic field modulation of the switching current. Moreover, local gates coupled with each junction provide a fine electrostatic control over the quantum state and coupling of each QD, which allows us to tune Kondo correlations. We finally measure, with a good agreement with theoritical predictions, the first experimental 0-p phase diagram of a carbon nanotube Josephson junction. [van Dam] J.A. van Dam, Y.V. Nazarov, E.P.A.M. Bakkers, S. De Fransceshi, L.P. Kouvenhoven, Nature 442, 667 (2006) [Cleuziou] J-P. Cleuziou, W. Wernsdorfer, V. Bouchiat, T. Ondarcuhu, M. Monthioux, Nat. Nanotech. 1, 53 (2006)

17h30 **T. Kontos** **Carbon nanotubes as Cooper pair beam splitters**

Quantum optics has been an important source of inspiration for many recent experiments in nanoscale electric circuits. One of the basic goals is the generation of entangled electronic states in solid state systems. Superconductors have been suggested as a natural source of spin entanglement, due to the singlet pairing state of Cooper pairs. One important building block required for the implementation of entanglement experiments using superconductors is a Cooper-pair beam splitter which should split the singlet state into two different electronic orbitals. The basic mechanism for converting Cooper pairs into quasiparticles is the Andreev reflection in which an originally quantum coherent electron pair in the singlet spin state is produced at an interface between a superconductor and a normal conductor. Conventional Andreev reflections are local and cannot readily be used to create bipartite states. Many theoretical proposals for circumventing this fact have been around for the last decade. It has been suggested to make use of electron-electron interactions, spin filtering or anomalous scattering in graphene to promote Cooper-pair splitting, i.e., the crossed Andreev reflection process. In this work, we have used Coulomb interactions as well as size quantization in order to favor the crossed Andreev reflection processes in carbon nanotubes, realizing experimentally an efficient Cooper pair splitter [1,2]. The devices studied are double quantum dots which can be viewed as artificial molecules connected to one superconducting reservoir and two normal reservoirs. Thanks to their tunability, they allow to change in situ the probability of emitting spit Cooper pairs. These findings open an avenue for more complex quantum optics like experiments with electronics sates which should allow, among other things, to test the coherence of the emitted split Cooper pairs. [1] L. G. Herrmann, F. Portier, P. Roche, A. Levy Yeyati, T. Kontos, and C. Strunk Phys. Rev. Lett. 104, 026801 (2010). [2] L. Hofstetter, S. Csonka, J. Nygard, and C. Schönenberger, Nature 461, 960 (2009).

17h50 **P. Jacquod** **STM Spectroscopy of ultra-flat graphene on hexagonal boron nitride**

Graphene has demonstrated great promise for future electronics technology as well as fundamental physics applications because of its linear energy-momentum dispersion relations which cross at the Dirac point. However, accessing the physics of the low density region at the Dirac point has been difficult because of the presence of disorder. The latter leaves the graphene with local microscopic electron and hole puddles, resulting in a finite density of carriers even at the charge neutrality point. Efforts have been made to reduce the disorder by suspending graphene, leading to fabrication challenges and delicate devices which make local spectroscopic measurements difficult. Recently, it has been shown that placing graphene on hexagonal boron nitride (hBN) yields improved device performance. In this talk, I will present STM results showing that graphene conforms to hBN, as evidenced by the presence of Moir\'{e} patterns in the topographic images. However, contrary to recent predictions, this conformation does not open a band gap due to the misalignment of the lattices. Local spectroscopy measurements demonstrate that the electron-hole charge fluctuations are reduced by two orders of magnitude as compared to those on silicon oxide. This leads to charge fluctuations which are at least as small as in suspended graphene, opening up Dirac point physics to more diverse experiments than are possible on freestanding devices. Collaboration with the experimental groups of B. LeRoy (Arizona) and P. Jarillo-Herrero (MIT).

18h20 **Coffee**

18h50 **A. Bachtold** **Electromechanical resonators based on graphene and carbon nanotubes**

Carbon nanotubes and graphene offer unique scientific and technological opportunities as nanoelectromechanical systems (NEMS). Namely, they have allowed the fabrication of mechanical resonators that can be operable at ultra-high frequencies and that can be employed as ultra-sensitive sensors of mass or charge. In addition, nanotubes and graphene have exceptional electron transport properties, including ballistic conduction over long distances. Coupling the mechanical motion to electron transport in these remarkable materials is thus highly appealing. In this talk, I will review some of our recent results on nanotube and graphene NEMSs, including the control of the mechanical oscillation using individual electrons tunneling onto and out of the nanotube, and the study of the thermal contraction of nanotubes.

19h10	**S. Gueron**	**Impurity scattering in coherent and incoherent single and bilayer graphene** The nature of the scatterers which to this day limit the mobility of graphene, and determine most of its conduction properties, is still highly debated. Some groups attempt to deduce the nature of these scatterers from the effect of the dielectric surrounding the graphene. I will describe our approach in Orsay, which consists in comparing two different scattering times, the elastic scattering time and the transport scattering time, which play different roles in the magnetoresistance of the samples. I will show that the ratio of these two times, as well as their dependence with charge density, point to dominant scattering originating from strong, neutral, short range scatterers, rather than from charged impurities. I will also present a consequence on quantum transport of the existence of these scatterers, namely, the reproducible conductance fluctuations in these samples at low temperature, when the quantum coherence extends over the entire sample length. We exploit the possibility to control the diffusion constant with gate voltage in monolayer and bilayer graphene to test the theory of mesoscopic fluctuations. We find that the correlation energy is given by the Thouless energy, and that the correlation field corresponds to a magnetic flux quantum threading a coherent area in the sample. But we find that the ergodicity hypothesis is not verified: the gate-voltage dependent fluctuations vary with gate voltage, and are largest near the charge neutrality point, whereas the magnetic field dependent fluctuations do not change with doping. The percolating nature of transport near the charge neutrality point may explain this unexpected result. In both experiments, we exploit the asset of monlayer and bilayer graphene, namely the fact that the different band structures lead to different gate-voltage dependences of the diffusion coefficients, enabling a quantitative test of theories over broad ranges, impossible to realize with other materials. Refs.: ?Transport and elastic scattering times as probes of the nature of impurity scattering in single and bilayer graphene?, M. Monteverde, C. Ojeda-Aristizabal, R. Weil, M. Ferrier, S. Guéron, H. Bouchiat, J.N. Fuchs, D.Maslov, Phys. Rev. Lett. 104, 126801 (2010). ?Conductance fluctuations and field asymmetry of rectification in graphene?, C. Ojeda-Aristizabal, M. Monteverde, R.Weil, M. Ferrier, S. Gueron, H. Bouchiat, Phys. Rev. Lett. 104, 186802 (2010).
19h30	**K. Efetov**	**Radiation induced photocurrent and quantum interference in n-p junctions.** We study transport properties of graphene-based and other low-dimensional n-p junctions irradiated by an electromagnetic field (EF). We concentrate on a regime, when the resonant interaction of propagating quasiparticles with an external radiation opens a dynamical gap in their spectrum resulting in a strong modification of current-voltage characteristics of the junctions. We find that in the graphene-based junctions, a photocurrent flows through the junction without any DC bias voltage applied. We estimate the value of the photocurrent in different regimes corresponding to realistic parameters of the experiments. It is demonstrated that the estimated values of this current are in a good agreement with those obtained in recent experiments. A radiation-induced quantum interference is predicted in low-dimensional n-p junctions based on low dimensional systems with an intrinsic gap in the electronic spectrum. This phenomenon manifests itself by large oscillations of the photocurrent as a function of the gate voltage or the frequency of the radiation. The oscillations result from the quantum interference between two electron paths accompanied by resonant absorption of photons. They resemble Ramsey quantum beating and Stueckelberg oscillations well-known in atomic physics. The effect can be observed in one- and two-dimensional n-p junctions based on nanowires, carbon nanotubes, monolayer or bilayer graphene nanoribbons.
19h50	Dinner	
21h00		**Poster session 2**

Thursday 17 March 2011

FQHE, abelian/non-abelian topological excitations, electronic correlations in low D

9h00 **A. Stern**

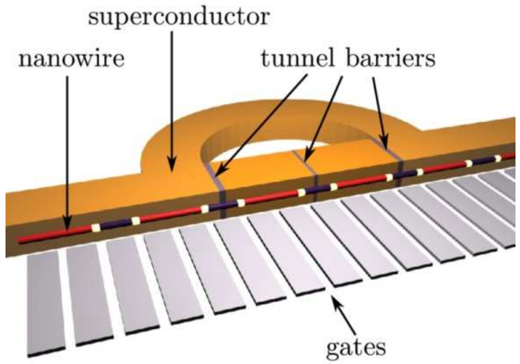
Interferometry and Coulomb blockade in abelian and non-abelian quantum Hall states

I will discuss the information that interferometry and Coulomb blockade experiments may give on the topological order of quantum Hall states, both abelian and non-abelian. In particular, I will compare the two types of experiments, discuss Coulomb blockade in the non-linear regime, and discuss the significant effect of Coulomb interactions on interferometers far from the Coulomb blockade limit.

9h50 **F. Hassler**

Anyonic interferometry without anyons: How a flux qubit can read out a topological qubit

Proposals to measure non-Abelian anyons in a superconductor by quantum interference of vortices suffer from the predominantly classical dynamics of the normal core of an Abrikosov vortex. We show how to avoid this obstruction using coreless Josephson vortices, for which the quantum dynamics has been demonstrated experimentally. The interferometer is a flux qubit in a Josephson junction circuit, which can nondestructively read out a topological qubit stored in a pair of anyons --- even though the Josephson vortices themselves are not anyons. The flux qubit does not couple to intra-vortex excitations, thereby removing the dominant restriction on the operating temperature of anyonic interferometry in superconductors.



10h10	**E. Sukhorukov**	**Theory of fractional quantum Hall interferometers** Interference of fractionally charged quasi-particles is expected to lead to Aharonov-Bohm oscillations with periods larger than the flux quantum. However, according to the Byers-Yang theorem, observables of an electronic system are invariant under adiabatic insertion of a quantum of singular flux. We resolve this seeming paradox by considering a microscopic model of an electronic interferometer made from a quantum Hall liquid at filling factor 1/m in the shape of a Corbino disk. Quantum Hall edge states are utilized in place of optical beams, quantum point contacts play the role of beam splitters connecting different edge channels, and Ohmic contacts may be considered a source and drain of a quasi-particle current. Depending on the position of Ohmic contacts one distinguishes interferometers of Fabry-Perot (FP) and Mach-Zehnder (MZ) type. An approximate ground state of such interferometers is described by a Laughlin type wave function, and low-energy excitations are incompressible deformations of this state. We construct a low-energy effective theory by projecting the state space of the liquid onto the space of incompressible deformations and show that the theory of the quantum Hall edge so obtained is a generalization of a chiral conformal field theory. A quasi-particle tunneling operator in our theory is found to be a single-valued function of tunneling point coordinates, and its phase depends on the topology, determined by the positions of Ohmic contacts. We describe strong coupling of the edge states to Ohmic contacts and the resulting quasi-particle current through the interferometer with the help of a master equation. We find that the coherent contribution to the average quasi-particle current through MZ interferometers vanishes after the summation over quasi-particle degrees of freedom. Remaining contribution originates from electron tunneling and oscillates with the electronic period, in agreement with the Byers-Yang theorem. Importantly, in contrast to previous models our theory does not rely on any ad-hoc constructions, such as Klein factors, etc. When a magnetic flux through FP interferometers is varied with a modulation gate, current oscillations have the quasi-particle periodicity, thus allowing for the spectroscopy of quantum Hall edge states.
10h40	Coffee	
11h10	**S. Das**	**Spin polarised scanning tunneling probe for helical Luttinger liquids** We propose a three terminal spin polarized stm setup for probing the helical nature of the Luttinger liquid edge state that appears in the quantum spin Hall system. We show that the three-terminal tunneling conductance strongly depends on the angle (θ) between the magnetization direction of the tip and the local orientation of the electron spin on the edge while the two terminal conductance is independent of this angle. We demonstrate that chiral injection of an electron into the helical Luttinger liquid (which occurs when θ is zero or π) is associated with fractionalization of the spin of the injected electron in addition to the fractionalization of its charge. We also point out a spin current amplification effect induced by the spin fractionalization.

11h40	**I. Safi**	**How to measure tunnelling charges without recourse to current noise?**

In low dimensional conductors, electronic correlations can give rise to quasi-particles carrying an electric charge q different from the elementary electron charge e. This is for instance the case for Cooper pairs, with a ?charge? equal to 2e. Whereas it is natural to conceive multiples of e, surprisingly, q can even be smaller! A fascinating example is that of fractionally charged Laughlin quasi-particles (1) in a two-dimensional electron gas subject to a perpendicular magnetic field: the fractional quantum Hall effect (FQHE). Even more, these are expected to obey ?exotic? statistics, which are neither bosonic nor fermionic (such as anyons or even ?non-abelian?). Detecting and measuring the fractional charge q is a crucial step towards understanding the properties of such systems and revealing those ?exotic? statistics. Nevertheless, even though success has been achieved for the well known state occurring at filling factor (ratio of the electron density to the flux density) equal to 1/3 (see Ref. 2) this issue is still subject to
controversies for other filling factors: theory and experiment have so far not been reconciled. (3) One major difficulty arises from the currently used detection methods of the fractional charge, based on shot noise measurement. In addition, the latter requires voltages which are high compared to temperature, and low compared to the excitation gap: such restrictions could lead to heating or to a too low signal. We propose novel and promising alternative methods (4) based on photo-assisted current or low frequency AC conductance. They are much easier to measure compared to shot noise; they still apply to the same tunnelling geometry and do not require any knowledge of the underlying model, being in particular independent on the description of edges states (whether smooth or sharp, coupled to the electromagnetic environment or not etc?). Another advantage of these methods is that they could be preformed for any voltage and temperature ranges. They apply in both limits of weak tunnelling and strong coupling. Thus they would be useful to detect the effective charge if edge states are coupled strongly to a normal or a superconductor electrode. More generally, these methods apply to tunnelling (possibly time-dependent) between two
conductors in arbitrary dimension with strong correlations. The conductors can be similar or different (hybrid structures), provided the super-current is negligible. In addition to the determination of charge, our study offers universal relations for time-dependent transport in Tunnel junctions between arbitrary correlated conductors. We have shown that both the finite frequency current average and current fluctuations (5) under arbitrary time-dependent voltage can be expressed in terms of the DC current. Thus we have generalized to large extent the Tien-Gordon theory of photo-assisted tunnelling, and have unified previous works specific to interacting one-dimensional systems or to simple fractional values of the filling factor (i. e. of the form 1/(2n+1) with n integer) in the FQHE. 1- R. B. Laughlin, Phys. Rev. Lett. 50, 1395 (1983). 2- L. Saminadayar et al, Phys. Rev. Lett. 79, 2526 (1997). R. de-Picciotto et al, Nature, 389, 162 (1997). 3- M. Dolev et al, Nature 452, 829 (2008); Radu et al, Science, 320, 899 (2008) 4- I. Safi and E. V. Sukhorukov, Europhysics Letters 91 (2010) 67008. 5- I. Safi and P. Joyez, in preparation.

12h10	**A. Chepelianskii**	**Microwave stabilization of edge transport and zero-resistance states**

In ultrahigh mobility two dimensional electron systems the longitudinal resistance Rxx can vanish under microwave irradiation for certain ratios between the microwave and cylclotron frequencies. This spectacular effect has become known as microwave induced zero-resistance states (ZRS). I will present new theoretical and experimental arguments which show that edge transport plays an important role in understanding this effect. I will show theoretically that a microwave field can stabilize propagation along sample edge against small angle scattering, leading to the formation of ballistic edge channels. I will then describe recent experiments which confirm the importance of edge effects ZRS.

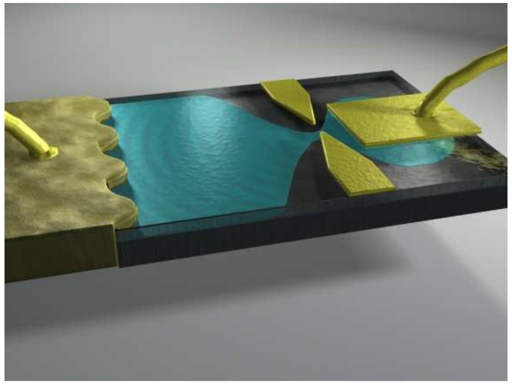
12h30	Lunch

Quantum dynamics, High frequency and time dependent phenomena, charge manipulation, quantum shot noise and full counting statistics

16h30	**M. Büttiker**	**Single electron emitters**
17h20	**G. Fève**	**Current correlations of an on-demand single electron emitter.** Ballistic electronic transport along the Quantum Hall edge states of two-dimensional electron gases presents strong analogies with the propagation of photons which have been illustrated, for example, by the realization of Mach-Zehnder interferometers [1]. Provided that one can produce on-demand single electronic states, these analogies can be pushed to quantum optics, based on the manipulation of single particles. Some celebrated quantum optics experiment, such as the single particle Hanbury-Brown and Twiss or the two particles Hong-Ou Mandel , could then be implemented in solid state with electrons. The achievement of these experiments relies both on the ability to produce these single electron states and on the ability to measure the output correlations between single electron beams. In analogy with quantum optics, we present the use of short time current-current correlations to characterize a recently realized electron source that periodically emits a single electron propagating along a chiral edge channel [2]. When exactly a single charge is emitted, the current noise reduces to a fundamental limit that demonstrates single particle emission and that is given by the fluctuations in the emission time (or 'jittering') of a single charge [3,4]. In the opposite limit where the probability of charge emission per cycle is low, usual shot noise is recovered. [1] Y. Ji et al., Nature 422, 415 (2003) . [2] G. Fève et al., Science 316, 1169 (2007). [3] A. Mahé et al., Phys. Rev. B 82, 201309 (2010). [4] M. Albert et al., Phys. Rev. B 82, 041407 (2010).
17h40	**P. Degiovanni**	**Electron quantum optics in quantum Hall edge channels** The recent demonstration of an on demand single electron source [1,2] has opened the way to a new generation of "electron quantum optics" experiments aimed at preparing, manipulating and measuring coherent single electron excitations propagating in ballistic conductors such as the edge channels of a 2DEG in the integer quantum Hall regime. In this talk, I will describe a recent proposal [3] for measuring single electron coherence using an Hanbury Brown and Twiss interferometer. This quantum tomography protocol could be used to characterize single electron sources and to perform quantitative studies of decoherence. I will then discuss theoretical results on the decoherence of single electron excitations due to e/e interactions or due to capacitive couplings with other conductors [4,5]. [1] Science 316, 1169 (2007) [2] Phys. Rev. B 82, 201309 (2010) [3] Preprint ArXiv:1010.2166 [4] Phys. Rev. B 80, 241307(R) (2009) [5] Phys. Rev. B 81, 121302(R) (2010)
18h00	Coffee	

18h30	**C. Mora**	**Universal Resistances of the Quantum RC circuit**

We discuss the capacitance and the resistance, usually called the charge relaxation resistance, of a quantum coherent RC circuit driven by a low-frequency AC voltage. This circuit is the quantum analogue of the classical RC circuit: it comprises a dot capacitively coupled to a nearby gate and connected to a single reservoir lead. As a result of phase coherence and electronic interactions, the quantum circuit behaves quite differently and Kirchhoff's law is violated. Here we show that the charge relaxation resistance is perfectly quantized, regardless of the single lead transmission and for an arbitrary strength of the interaction. Its low-frequency value is h/2 e^2. When the driving frequency exceeds the dot level spacing, we predict a transition to a metallic regime with a doubled quantized resistance h/e^2. The novel quantized resistance h/e^2 is connected to the Korringa-Shiba relation of the Kondo model, thereby revealing the physics behind these universal charges. [1] C. Mora and K. Le Hur Nature Physics 6, 697 (2010)



18h50	**T. Jonckheere**	**Dynamic response of a mesoscopic capacitor in the presence of strong electron interactions**

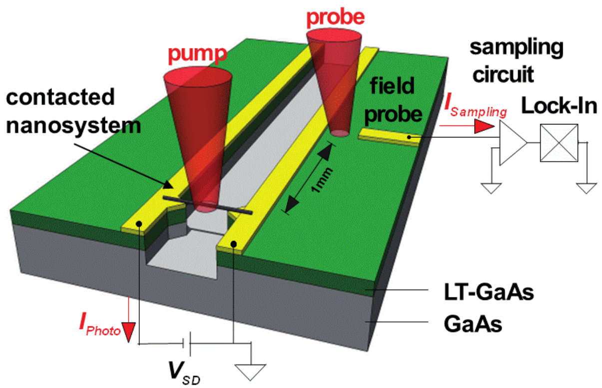
We consider a one dimensional mesoscopic capacitor in the presence of strong electron interactions and compute its admittance in order to probe the universal nature of the relaxation resistance. We use a combination of perturbation theory, renormalization group arguments, and quantum Monte Carlo calculation to treat the whole parameter range of dot-lead coupling. The relaxation resistance is universal even in the presence of strong Coulomb blockade when the interactions in the wire are sufficiently weak. We predict and observe a quantum phase transition to an incoherent regime for a Luttinger parameter K<1/2. Results could be tested using a quantum dot coupled to an edge state in the fractional quantum Hall effect. (ref.: Phys. Rev. B 81, 153305 (2010))

19h10	**P. Hakonen**	**Current-current correlations and exchange effects in multiterminal diffusive conductors**

We have measured auto- and cross-correlations of current fluctuations from different terminals in diffusive metallic samples. In our experiments, we employed biasing conditions which allowed for the extraction of the exchange interference effects that are analogous to the Hanbury Brown-Twiss effect in optics. Most of our results have been obtained on cross-shaped geometries, manufactured lithographically using copper wires with cross-sectional dimensions of 10x100 nm^2. For auto- and cross-correlations, we find good agreement with the standard theoretical calculations (see, e.g. Ya. Blanter and M. Buttiker, Phys. Rev. B 56, 2127 (1997); E. Sukhorukov and D. Loss, Phys. Rev. B 59 13054 (1999)). For the exchange effects, we find behavior that is reminiscent of a box type of sample rather than of a cross geometry. Extension of these experiments in to graphene is underway, and first experimental results on exfoliated graphene have been obtained.

19h40	**A. Holleitner**	**Picosecond time-resolved optoelectronic transport in nanoscale circuits**

The time-resolved dynamics of photogenerated charge carriers in nanoscale systems are typically detected by optical techniques such as the transient absorption technique and the time-resolved photoluminescence spectroscopy. Many questions remain concerning the separation and the transport of photo-generated charge carriers to source and drain leads, when the nanosystems shall be functional modules in electronic circuits. Typical propagation times of ballistic photogenerated charge carriers in nanoscale circuits, which comprise semiconductor nanowires and quantum wires, are in the ps-regime [1,2]. Conventional electronic measurements cannot resolve such ultrafast dynamics because available electronic equipment cannot produce trigger signals and detect transients faster than tens of picoseconds. Furthermore, nanosystems typically exhibit a high impedance of several kilo-ohms, and ultrafast charge-carrier dynamics are therefore obscured by the response time of the high-frequency circuits. Here, we introduce an experimental on-chip scheme to measure the photocurrent dynamics of electrically contacted nanosystems in the time domain. The technique applies an ultrafast optical pump-probe scheme to a coplanar stripline circuit, and the photocurrent response of the nanosystems is sampled by a field probe (see figure and [3]). The experimental setup with a picosecond time-resolution will be introduced, and first results of the ultrafast time-resolved photocurrent dynamics in contacted carbon nanotubes and graphene will be shown [4]. We will discuss polarization, plasmonic as well as charge transport effects within the nanosystems, the relaxation of the photogenerated charge-carriers, and the influence of contacting the nanosystems by electrodes. [1] C. Ruppert, S. Thunich, G. Abstreiter, A. Fontcuberta i Morral, A.W. Holleitner, and M. Betz, Nano Letters 10 (5), 1799 (2010). [2] K.-D. Hof, F.J. Kaiser, M. Stallhofer, D. Schuh, W. Wegscheider, P. Hänggi, S. Kohler, J. P. Kotthaus, and A.W. Holleitner, Nano Letters 10 (10), 3836 (2010). [3] L. Prechtel, S. Manus, D. Schuh, W. Wegscheider, and A.W. Holleitner, Applied Physics Letters 96, 261110 (2010). [4] L. Prechtel, L. Song, S. Manus, D. Schuh, W. Wegscheider, and A.W. Holleitner, Nano Letters, accepted, http://pubs.acs.org/doi/pdf/10.1021/nl1036897 (2010).



20h10	Dinner

Friday 18 March 2011

Qubits with Cavity Quantum Electrodynamics circuits Quantum entanglement with itinerant charge and spins.

9h00 **D. Estève** **Electrical circuits for quantum physics and quantum information**

9h50 **M. Hofheinz** **The bright side of Coulomb blockade**

The electromagnetic environment of a tunnel junction can modify the current through it because the sudden charge transfer associated with a tunnel event can generate photons in the environment. This dissipation process, called dynamical Coulomb blockade (DCB), tends to reduce the current through a normal metal junction at low bias and in the case of a Josephson junction allows for a Cooper pair current at non-zero bias voltage [1]. DCB has been extensively studied and is well understood [2], yet the radiation emitted into the electromagnetic environment has never been observed. With the advent of circuit quantum electrodynamics, the quantum properties of the emitted photons could now become useful. We explore this bright (photonic) side of DCB by measuring the radiation emitted by a voltage-biased Josephson junction embedded in a microwave resonator. We have measured simultaneously the Cooper pair current and the photon emission rate at the resonance frequency of the resonator. Our results show two regimes in which each tunneling Cooper pair emits either one or two photons into the resonator. The spectral properties of the emitted radiation are accounted for by an extension to DCB theory. [1]

10h20 **E. Buks** **Intermode Dephasing in a Superconducting Stripline Resonator**

We study a superconducting stripline resonator (SSR) made of Niobium, which is integrated with a superconducting quantum interference device (SQUID). The large nonlinear inductance of the SQUID gives rise to a strong Kerr nonlinearity in the response of the SSR, which in turn results in strong coupling between different modes of the SSR. We experimentally demonstrate that such intermode coupling gives rise to dephasing of microwave photons. The dephasing rate depends periodically on the external magnetic flux applied to the SQUID, where the largest rate is obtained at half integer values (in units of the flux quantum). To account for our result we compare our findings with theory and find good agreement.

10h40 Coffee

11h10 **F. Lecocq** **Two-Dimensional quantum dynamic in a dc SQUID**

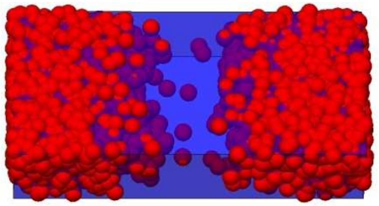
F. Lecocq, I. M. Pop, Z. Peng, I. Matei, C. Naud, F. W. Hekking, W. Guichard, O. Buisson (Institut Neel, CNRS, Grenoble, France) R. Dolata, A. B. Zorin (PTB, Braunschweig, Germany) The dynamics of a dc SQUID presents a large variety of quantum effects at very low temperature such as 2D MQT signature, multilevel and phase qubit dynamics. We have shown that along the zero current bias line, the quantum dynamics is protected from current fluctuations. Along this line, the potential is quadratic-quartic and enhanced phase qubit properties have been demonstrated [1]. When the dc SQUID loop inductance is of the order of the Josephson inductance the dynamic becomes two dimensional. As a consequence, in addition to the oscillation mode producing the phase qubit, a second oscillation mode exists, called transverse mode. Here we report spectroscopic evidence and coherence properties of both oscillators as well as coherent oscillations between the quantum states of these two coupled oscillators. Supported by the EU project EuroSQIP and SOLID, and ANR QUANTJO. [1] Quantum dynamics in a camel-back potential of a dc SQUID, E. Hoskinson, et al, Phys. Rev. Lett. 102, 097004 (2009).

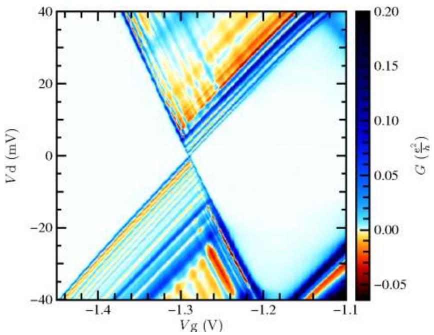
11h30	**F. Hekking**	**Phase-Charge Duality in Josephson junction chains** We theoretically investigate the physics of coherent quantum phase slips in chains of Josephson junctions. The collective behaviour of such a chain can be characterized by one variable: the number of quantum phase slips present on it. We formulate the conditions under which the dynamics of the conjugate quasi-charge is exactly dual to the well-known phase dynamics of a single Josephson junction. This conclusion has profound consequences for the behaviour of Josephson junction chains under microwave irradiation: we expect the appearance of accurate current-Shapiro steps at multiples of the applied microwave frequency, a result that is of interest in view of a metrological current standard. Recent experimental findings indicate that finite size effects as well as effects associated with the existence of a finite capacitance of the chain to ground play an important role. We present a simple model that accounts for these effects and show how they modify the phase-slip amplitude and influence the collective behaviour of the chain. Our results compare favourably to the results of the experiments.
11h50	**G. Lesovik**	**Correlations in quantum conductors -- postselection and violation of the Tsirelson bound for Bell inequality**
12h10	**C. Eichler**	**Tomography and Correlation Function Measurements of Itinerant Microwave Photons** A wide range of experiments studying microwave photons localized in superconducting cavities have made important contributions to our understanding of the quantum properties of radiation. Propagating microwave photons, however, have so far been studied much less intensely. Here we present measurements in which we characterize the radiation emitted from a pulsed single photon source. We measure temporal correlation functions as well as the Wigner function for itinerant single photon Fock states and their superposition with the vacuum using linear amplifiers and quadrature amplitude detectors. We have developed efficient methods to separate the detected single photon signal from the noise added by the amplifiers by analyzing the moments of the measured amplitude distribution up to 4th order. These results provide new tools for the detailed study of propagating microwaves in the context of quantum optics.C. Eichler, D. Bozyigit, C. Lang, L. Steffen, J. Fink, M. P. da Silva, A. Blais, and A. Wallraff. Nat. Phys. 7, 154 (2011); arXiv:1011.6668 (2010); Phys. Rev. A 82, 043804 (2010).
12h40	Lunch	
		Mesoscopics of hybrid systems: superconducting/ferro/normal/Kondo
17h00	**J. Splettstoesser**	**Adiabatic transport through quantum dots with Coulomb interaction** Adiabatically time-dependent transport through quantum dots can give access to quantum coherence and Coulomb interaction effects, which are not directly revealed from the study of a time-independent system. In the work which I will present here [1], we studied the time-dependent current in presence of a non-linear voltage through a quantum dot with a finite and possibly large Coulomb interaction in the single-electron tunneling regime (SET). Gate and bias voltage which are applied to the quantum dot are varied adiabatically in time with a respective phase difference. The finite Coulomb interaction on the quantum dot generates an additional dc current. This current can arise only when two SET resonances are fulfilled simultaneously. With these findings we propose a novel adiabatic transport spectroscopy using lock-in measurements of a "time-averaged stability diagram". This is a useful tool to probe Coulomb interaction, tunnel coupling asymmetries and differing spin degeneracies in the ground state in a gentle way. [1] F. Reckermann, J. Splettstoesser, and M. R. Wegewijs, Phys. Rev. Lett. 104, 226803 (2010).

17h20 **A. Freyn** **Production of Andreev quartets and phase-sensitive correlations in a three-terminal Josephson set-up**

Axel Freyn^1, Benoit Doucot^2, Denis Feinberg^1, Régis Mélin^1 1: Institut NEEl, CNRS and Université Joseph Fourier, BP 166, 25 Avenue des Martyrs, 38042 Grenoble cedex 9, France 2: Laboratoire de Physique Théorique et des Hautes Energies, CNRS UMR 7589, Universités Paris 6 et 7, 4 Place Jussieu, 75252 Paris cedex 05, France We show that three BCS superconductors in a three-terminal SNSNS-setup can be used to produce correlated quartets of electrons, which stem from the central superconductor and are spatially separated as two pairs in two different superconductors. Quartet productions becomes significant if the distance between the two interfaces is smaller than the superconducting coherence length in the central superconductor. This process of quartet-production contributes to low-temperature transport at equilibrium. Replacing the normal leads at the contacts by n- and p-doped semiconductors allows to block other transport channel like elastic cotunneling or crossed Andreev reflection, increasing the relative importance of Quartet processes. The quartets being emitted coherently in both superconductors, the current noise measured in the setup will show phase-sensitive quantum correlation. We show that the resulting groundstate is an entangled "squeezed state" similar to those known from quantum photonics or cold atom gases. Ref.: A. Freyn, B. Doucot, D. Feinberg, R. Melin (to appear)

17h40 **X. Jehl** **Ionization energy and transport through single dopant atoms in tunable SET/FET silicon devices**



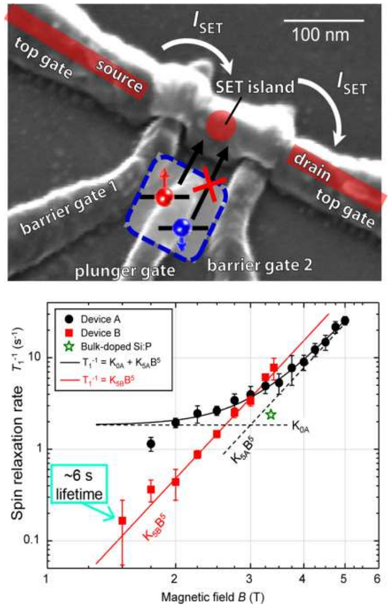


We measure the ionization energy of one isolated arsenic dopant in a very small silicon channel. Complex multiple donors effects are negligible in such small volumes and low concentration of donors. However, as expected, the spectrum of an isolated donor is markedly different in such a confined volume than in an infinite host cristal [1]. Our precise spectroscopy technique relying on direct transport through a single impurity allows to locate the dopant under study very near the buried oxide. The ionization energy is found to be up to twice the value calculated for a bulk Si host crystal [2], because of the dielectric confinement effect near the Si/SiO2 interface [3]. The variability of this ionization energy due to the exact position of the donor has a dramatic impact on the characteristics of our devices up to room temperature, providing a first experimental correlation between low and room temperature mesoscopic behaviour. The large sample-to-sample variability observed at 300K, due to thermally broadened transport through single dopant states, is also a major concern for microelectronics as it is a limiting factor for the most advanced circuits. Our samples are produced in a microelectronics CMOS facility. Silicon nanowire transistors with channels both short, narrow and thin (10x50x20 nm) are etched on silicon-on-insulator (SOI) wafers. In the past we have used this ultra thin SOI CMOS technique and a specific source/channel/drain contact architecture to engineer tunnel contacts and obtain very efficient and controllable single-electron transistors (SETs), with large charging energies. The barriers were fixed and Coulomb blockade spectroscopy allowed us to study single charge traps in great details [4]. Recently we have been able to tune in-situ these barriers and switch between excellent field-effect and single-electron transistors (FET/SET), by applying a substrate bias - a very unique opportunity with SOI substrates- while shining light onto the sample with an optical fiber [5]. This opens new perspectives for the study of the few-electron regime in silicon SETs, coupled SETs (logic-on-wire) [6], electron pumps and also quantum circuits, considering the appealing properties of silicon like its long spin relaxation time. [1] M. Pierre et al., Nature Nanotechnology 5. 133, 2010. [2] W. Kohn and J.M. Luttinger, Phys. Rev. 98, 915, 1955 [3] M. Diarra et al., Phys. Rev. B75, 045301, 2007. [4] M. Pierre et al., Eur. Phys. J. B. 70, 475, 2009. [5] B. Roche et al., in preparation. [6] M. Pierre et al. Applied Physics Letters 95, 242107, 2009.

18h00 **M. Mottonen**

Transport and single-shot spin readout of electron spins in silicon

The conduction channel, which is induced in a nano-scale metal-oxide-silicon field-effect transistor (MOSFET) by a top gate, can be locally depleted by a narrow barrier gate. Recently, the single-electron regime has been observed in a quantum dot defined by two nearby barrier gates [1]. Here, we report on experiments with devices similar to these but with additional phosphorus donors implanted in the vicinity. We have observed sequential electron tunneling through the sharp donor potential directly below a single barrier gate [2]. The direct current and conductance measurements show regions of transport of only a single or both of the electron spin states. We demonstrate also the in-situ control of the density of states in the electron reservoirs [3]. In the spin readout device, a quantum dot is used as a charge sensor, and the spin state of the electron trapped in the nearby donor potential can be read out by utilizing spin-to-charge conversion. We demonstrate a single-shot readout fidelity better than 90 per cent and spin lifetime of roughly 6 seconds at 1.5 tesla magnetic field [4]. The scheme is also employed to initialize the spin state. Future work will address coherent spin rotations, yielding a fully addressable and readable single-qubit register. [1] W. H. Lim et al., Appl. Phys. Lett. 95, 242102 (2009). [2] K. Y. Tan et al., Nano Lett. 10, 11 (2010). [3] M. M?tt?nen et al., Phys. Rev. B 81, 161304(R) (2010). [4] A. Morello et al., Nature (London) 467, 687 (2010). Figure caption: (top) Device and spin readout schematics. (bottom) Spin relaxation rate at different magnetic fields.



18h20 Coffee

18h50 **M. Wegewijs**

Spin-multipole-tronics - theory of hybrid nanoscale circuits with ferromagnets

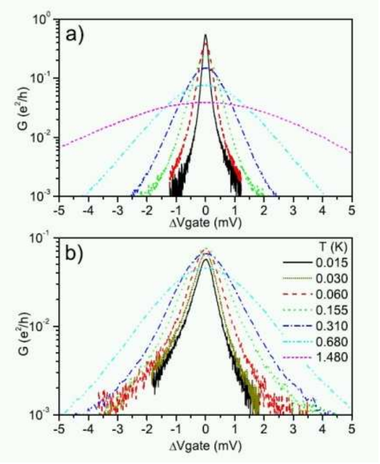
Quantum transport through circuits with ferromagnets has long been discussed in terms of an interplay of charge and spin-currents. In this talk I will show that this picture is in general incomplete. This issue arises concretely when electron spins can accumulate in a quantum dot with a many-body spin state with spin-length S > 1/2 in a circuit with ferromagnetic electrodes. Here the transport of spin-quadrupole (and higher) and spin-dipole moment (the usual spin-current) can become equally important. Accounting for the associated spin-multipole currents is in general crucial, since their interplay with the charge current establishes the stationary non-equilibrium state. The real-time transport theory outlined in this talk accounts for the usual transport of charge and spin-polarization, as well as \emph{transport of spin-anisotropy}, quantified by the spin multipole moments in the transport circuit. This establishes a new link between spin-tronics and molecular magnetism. The spin-multipole currents, which are tensors of rank 2 and higher, are shown to satisfy continuity equations (a Kirchoff law). I illustrate these ideas using simple circuits involving two ferromagnets coupled by (a) a simple tunnel barrier (b) by a low-spin (S=0 and 1/2) quantum dot and (c) a high-spin quantum dot (S=1/2 and 1). The spin-quadrupole current is found to be non-zero and to couple to the observable charge current, except for simple cases (a) and (b) where the concepts of charge and spin current are thus still sufficient. Finally, I present a novel spin-resonance in the charge current through a 3-terminal hybrid ferromagnet-quantum dot circuit, in which the spin-precession induced by Coulomb interaction can be probed and controlled electrically.

19h10 **S. De franceschi** **Spin-orbit interaction and Kondo effect in hybrid superconductor-semiconductor nanostructures**

Nanostructured materials such as self-assembled semiconductor quantum dots and nanowires are currently investigated as potential building blocks for a wide range of applications, from (opto)electronics to biochemical sensing. At the same time, such nanomaterials offer unique opportunities to create relatively simple and tunable electronic systems in which complex quantum phenomena can be explored. In this talk, I will focus on quantum-dot devices obtained by contacting individual semiconductor nanostructures such as indium arsenide nanowires or silicon-germanium self-assembled islands. I will present tunneling and co-tunneling spectroscopy measurements in a magnetic field. These measurements provide accurate information on the spin-related properties of the confined electronic states. In particular, we find strong g-factor anisotropies and asymmetries in the non-linear transport characteristics which can be interpreted as different evidences of a strong spin-orbit interaction. In the strong coupling regime and in the presence of superconductivity in the leads, a spin-1/2 quantum dot can form a Kondo system where Kondo exchange correlations compete with Cooper pairing correlations. We present a recent study of this competition where an external magnetic field is used to finely control the ratio between the Kondo temperature and the superconducting gap.

19h30 **G. Finkelstein** **Resonant Tunneling in a Dissipative Environment**

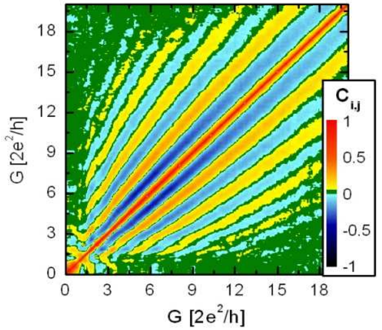
We measure tunneling through a single quantum level in a carbon nanotube in a dissipative environment. In the regime of sequential tunneling (temperature larger than the level width, Figure a), the height of the single-electron conductance peaks increases as the temperature is lowered, although the power law scaling is weaker than the conventional 1/T. In the resonant tunneling regime (temperature smaller than the level width), the peak width approaches saturation, while the peak height starts to _decrease_. Overall, the peak height shows a non-monotonic temperature dependence (Figure b). We associate this unusual behavior with the transition from the sequential to the resonant tunneling through a single quantum level in a dissipative environment. We draw a connection between our results and the recent theories on a quantum dot with Luttinger liquid leads.



19h50 **A. Halbritter**

Regular Atomic Narrowing of Ni, Fe, and V Nanowires Resolved by Two-Dimensional Correlation Analysis

A. Halbritter, P. Makk, Sz. Mackowiak, Sz. Csonka, M. Wawrzyniak, J. Martinek Conductance histogram technique is widely applied to identify the conductance of stable, frequently occurring atomic configurations or molecular contacts formed during the rupture of metallic nanowires. However, conductance histograms can rarely show much more than a single or a few configurations due to the stochastic nature of nanocontact formation dynamics. We demonstrate how several, yet undetected stable atomic configurations can be resolved by a novel method based on the cross-correlation analysis of conductance traces [1]. We show that in some transition metals the typical evolutions of the conductance staircase can be clearly followed starting from rather large contact diameters, which is completely hidden in traditional histograms due to correlated shifting of conductance plateaus. Our analysis opens a new window for resolving a very regular atomic narrowing of Ni, Fe and V nanowires, in contrast to the rather unordered rupture in the majority of the metals. [1] A. Halbritter, P. Makk, Sz. Mackowiak, Sz. Csonka, M. Wawrzyniak, and J. Martinek, Phys. Rev. Lett. 105, 266805 (December, 2010)



20h10 Conference dinner

Saturday 19 March 2011

Mesoscopics of hybrid systems: superconducting/ferro/normal/Kondo

9h30 **M. Aprili**

Phase Cooling

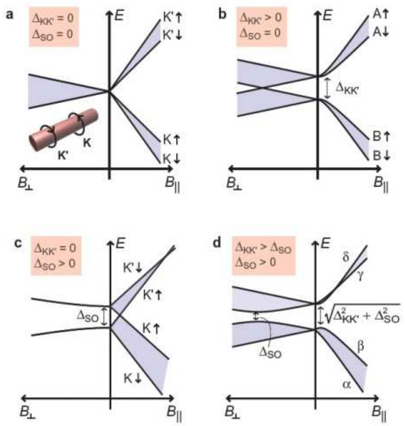
The radiation pressure is used for cooling atoms, ions and optomechanical devices. In a Fabry-Pérot interferometer in which one of the two mirrors vibrates, the Brownian motion of the vibrating mirror and hence its effective temperature can surprisingly be lowered by increasing the power of light. There is a straightforward analogy with a Josephson junction irradiated with microwave photons, where the phase difference between the wavefunctions of two superconductors, the Josephson phase, takes the role of the mirror position. The microwave field acts on the Josephson phase as the radiation pressure does on a vibrating mirror. Specifically, when coupled with a high quality microwave cavity, the Josephson junction generates sideband resonances for each cavity mode. Out-of-equilibrium phase heating or cooling is achieved by microwave radiation at these sidebands, corresponding to the Stokes and anti-Stokes scattering, respectively. Cooling and heating increase with microwave power.

Transport in Graphene, carbon nanotubes and point contacts

10h00 **J. Nygard**

Spin-orbit coupling in multi-electron carbon nanotube quantum dots

The coupling of the spin of electrons with their orbital motion is a central theme in current quantum dot research. For carbon nanotubes the coupling was overlooked in the first decade of experiments. Recently, spin-orbit interactions were observed in a disorder-free few-electron quantum dot [1]. Here we demonstrate the spin-orbit coupling in the general multi-electron regime (0-200 carriers) and in the presence of finite disorder [2]. The spin-orbit coupling is found to depend on the electron occupation of the dot in a systematic manner that follows from the curvature induced spin-orbit splitting of the Dirac cones for graphene. The modified spectrum is fully accounted for by a single-particle model. The work was carried out by T. S. Jespersen, K. Grove-Rasmussen, J. Paaske, J. Nygard, K. Flensberg (University of Copenhagen), K. Muraki (NTT), and T. Fujisawa (Tokyo Institute of Technology). Research supported by the Carlsberg and Lundbeck Foundations, the Danish Research Council and the University of Copenhagen Center of Excellence. [1] F. Kuemmeth et al, Nature 452, 448 (2008). [2] T.S. Jespersen, K. Grove-Rasmussen et al, Nature Physics (in press)



10h30 Coffee

11h00 **S. Andergassen**

Multi-level carbon nanotube quantum dots: reservoir-coupling induced renormalization effects

In carbon nanotube dots the fourfold level degeneracy with respect to the spin and valley index K, K' is lifted by intervalley coupling, resulting from disorder, the confining potential, spin-orbit interactions due to the tube curvature, or a magnetic field. Recent transport experiments confirm the single-particle level structure probed by cotunneling spectroscopy. In the basis of single-particle eigenstates of the isolated dot the inner four levels lead to pairs of strongly and weakly coupled levels in absence of magnetic field. In addition to the Kondo ridges at zero field, the crossings of levels originating from different shells give rise to Kondo ridges at finite magnetic field. The observed bending with respect to the Kondo ridges at zero field turns out be a consequence of the magnetic-field dependence of the level-reservoir coupling strengths. Theoretical understanding is provided by using the functional renormalization-group approach, which reproduces the features of the linear conductance measurements as a function of the applied gate voltage and magnetic field. In particular the bending of the Kondo ridges at finite magnetic field is traced back to the renormalization of the couplings.

11h20	**M. Gaass**	**Kondo Effect in single wall carbon nanotubes with ferromagnetic contacts** We investigate the influence of ferromagnetic contacts on the Kondo effect in quantum dots formed in SWCNTs. For this purpose we use Pd0.3Ni0.7, a ferromagnetic alloy known for providing sufficiently transparent interfaces to CNTs [1,2]. Transport spectroscopy shows a conductance anomaly around zero bias in every second Coulomb diamond. The ferromagnetic contacts cause two peaks at finite bias, which can be rejoined by a finite magnetic field. The size and sign of the splitting as well as its dependence on gate voltage can be explained by spin-dependent renormalization processes of the quantum dot level that include two contributions. The first, largely independent of gate voltage, arises from the macroscopic magnetization of the leads. The second contribution, showing a gate dependence, stems from the polarization of the spins at the Fermi energy. The data are compared to numerical renormalization group calculations. In addition, we observe a fine structure in the spectra indicating a complex level structure, which may result from curvature-induced spin-orbit interaction. [1] J.R. Hauptmann, et al., Nature Phys. 4, 373 (2008) [2] L. Hofstetter, et al., Phys. Rev. Lett. 104, 246804 (2010)
11h40	**M. Reznikov**	**Third cumulant in Quantum point Contacts**
12h00	Lunch	

QHE, edge transport and interaction

17h00	**H. Le sueur**	**Nature of Edge Excitations in the Integer Quantum Hall Regime** In the quantum Hall regime, charges propagate without dissipation in 1D channels along the edges of the sample. These edge channels present a similarity with light beams, which has inspired electronic analogues of quantum optics experiments, such as the Mach-Zehnder interferometer. However, contrary to photons, electronic excitations interact together and with their environment, through the Coulomb interaction. This offers new opportunities, for instance to implement fast quantum logic gates, but its main consequence is to limit the quasiparticles lifetime. The question thus arises of determining the nature of inelastic mechanisms at work in the quantum Hall regime. To directly access energy transfers, we probe the energy distribution of quasiparticles f(E) in an edge channel driven out-of-equilibrium [1]. Inelastic scattering occurs on a length scale related to the excited quasiparticles lifetime. By measuring f(E) for various propagation lengths, we can explore the edge?s dynamics: the inelastic mechanisms at work, and the nature of the pertinent electronic excitations. For the important case of two co-propagating ECs, we find a complete energy current equilibration, over a few micrometers. This strongly suggests that the dynamics is governed by collective edge excitations delocalized over the co-propagating channels [2, 3]. [1] Altimiras et al., Nature phys., doi:10.1038/nphys1429 (2009) [2] le Sueur et al., Phys. Rev. Lett. 105, 056803 (2010) [3] Degiovanni et al., Phys. Rev. B 81, 121302 (2010)
17h30	**E. Devyatov**	**Energy transfer at the reconstructed quantum Hall edge** Stable interest to edge states (ES) investigations in the quantum Hall regime is determined by their spectrum, which is characterized by chiral gapless collective modes. For some filling factors (1 and 1/3) strong interaction-driven edge reconstruction is predicted [1] as a result of the interplay between the smooth edge potential and the Coulomb interaction energy. The reconstructed edge allows counter-propagating neutral modes, with the latter carrying only energy. In a standard quantum point contact, the counter-propagating ES are at low imbalance, which prevents the efficient excitation of neutral mode. In this regime neutral modes were recently detected in the short-noise measurements [2], which are preferable because of much better sensitivity. Here, we realize a novel sample design which allows to independently investigate a charge and an energy transport along the edge. We enforce transport between co-propagating ES in one ES junction (injector), which is obligatory accompanied by the energy dissipation in a form of charged or neutral excitations. An independent ES junction serves as a detector. We experimentally observe an energy transfer contrary to the electrons' drift direction for filling factors 1 and 1/3. Our analysis indicates that a neutral collective mode at the interaction-reconstructed edge is a proper candidate for the experimentally observed effect. [1] Xin Wan, E. H. Rezayi, and Kun Yang, Phys. Rev. B 68, 125307 (2003) [2] Aveek Bid, Nissim Ofek, Hiroyuki Inoue, Moty Heiblum, Charles Kane, Vladimir Umansky, Diana Mahalu, Nature 466, 585, (2010).
18h00	**I. Levkivskyi**	**Noise-induced phase transition in the electronic Mach-Zehnder interferometer** Recently, Aharonov-Bohm (AB) effect in electronic Mach-Zehnder (MZ) interferometers has attracted much attention among experimental and theoretical physicists. These interferometers utilize quantum Hall edge states in place of optical beams, and quantum point contacts (QPC) as beam splitters, to partition edge channels. Theoretical attempts to explain experimentally observed puzzling lobe-type behavior of the visibility of AB oscillations as a function of voltage bias, have led to a number of publications. They have focused on the filling factor ?=1 state, and suggested different mechanisms of dephasing. To date, however, all the experiments, reporting multiple side lobes in the visibility function of voltage bias, have been done at filling factor ?=2. We will argue that, in fact, there are two main mechanisms of dephasing in MZ interferometers. One mechanism, due to spontaneous emission of edge magneto-plasmons, leads to a size effect, which explains the lobes and many other details of experiments. According to the second mechanism, dephasing in electronic MZ interferometers is due to an external

non-equilibrium noise source. Experimentally, such a noise is created with the help of an additional QPC with the transparency T that partitions incident edge channels. We predict that a phase transition occurs at T=1/2, where the visibility function of voltage bias sharply changes its behavior. An important role in this phenomenon is played by a non-Gaussianity of noise, which is typically negligible because of a weak coupling. It turns out that MZ interferometers are strongly coupled to noise. They, therefore, can be considered efficient detectors of full counting statistics.

18h20	Coffee	
18h50	**A. Lebedev**	**Dynamical resurrection of the visibility in a Mach-Zehnder interferometer** On demand single-electron sources are an essential building block in the controlled quantum state manipulation in nanoscale devices. The theoretical idea how to generate such pulses has been proposed more than a decade ago and first experimental results have been reported recently. Contrary to their optical counterparts, the photons, such single-electron states are prone to decoherence due to the interaction with the underlying Fermi-sea. In this article we study the influence of a capacitive Coulomb interaction on a single-electron wave-packet injected into the chiral edge state of a Quantum Hall device. Due to the interaction, the injected particle exchanges energy with the underlying Fermi sea and thus excites electron- hole pairs. Analyzing the resulting scattering state, we find, to our surprise, that it remains unentangled. As a result, we can equally well generate the scattered many- particle state by application of a specific voltage pulse applied locally to the system. This equivalence allows one to undo the effects of decoherence by applying a suitable (inverse) voltage pulse und thus to recover the original single-particle wave packet. As a test and first application of our findings we consider an asymmetric Max- Zehnder interferometer where electrons passing through one arm are subjected to a capacitive Coulomb interaction. It turns out that applying a suitable voltage pulse to the scattered state behind the interaction region, the visibility of the interference pattern can be improved considerably though not perfectly.
19h10	**F. Battista**	**Proposal for non-local electron-hole turnstile in the Quantum Hall regime.** We present a theory [1] for a mesoscopic turnstile that produces spatially separated streams of electrons and holes along edge states in the quantum Hall regime. For a broad range of frequencies in the non-adiabatic regime the turnstile operation is found to be ideal, producing one electron and one hole per cycle. The accuracy of the turnstile operation is characterized by the fluctuations of the transferred charge per cycle. The fluctuations are found to be negligibly small in the ideal regime. [1] F. Battista, P. Samuelsson, arXiv:1006.0136
19h30	**H-S. Sim**	**A capacitive interaction model for an electron interferometry in the quantum Hall regime** We theoretically develop a capacitive interaction model for an electron interferometry in the quantum Hall regime, to understand the effect of electron-electron interactions on the interference signal of the interferometry. We first apply it to study Aharonov-Bohm resonances in an antidot system with multiple bound modes in the integer quantum Hall regime [1,2,3]. We find the spectator behavior that the resonances of some modes disappear and instead are replaced by those of other modes, due to internal charge relaxation between the modes. This behavior is a possible origin of the features of previous experimental data which remain unexplained, spectator behavior in an antidot molecule [4] and resonances in a single antidot with three modes [5]. Second, we extend the model to Aharonov-Bohm interference signals of an electronic Fabry-Perot interferometry in the quantum Hall regime [6], and compare the result with the case of an antidot system. References [1] H.-S. Sim, M. Kataoka, and C. J. B. Ford, Phys. Rep. 456, 127 (2008). [2] W.-R. Lee and H.-S. Sim, Phys. Rev. Lett. 104, 196802 (2010). [3] W.-R. Lee and H.-S. Sim, arXiv:1009.1004 (2010). [4] C. Gould et al, Phys. Rev. Lett. 77, (1996). [5] V. J. Goldman et al., Phys. Rev. B 77, 115328 (2008). [6] N. Ofek et al, PNAS 107, 5276-5281 (2010).
19h50	Dinner	

Sunday 20 March 2011

Quantum Dots & Point Contacts

9h30 **T. Meunier** **Kondo effect in side-coupled quantum dots**

The Kondo effect arises when a single magnetic impurity is tunnel coupled to a Fermi sea. The essence of this highly correlated electron state is found in the non-perturbative nature of the exchange interaction between the local moment and the surrounding conduction electrons. It leads to a non-magnetic ground state at zero temperature. All the physical quantities of the system then scale with a unique energy scale, the Kondo temperature TK. Laterally defined quantum dots offer great possibilities to investigate in more detail the Kondo effect. In particular, constraining the Fermi Sea to a finite region and studying how this influences the screening of the local moment appears to be a crucial question in the Kondo problem. Here we will present transport measurements through a double quantum dot where a small quantum dot acting as a magnetic impurity will be tunnel-coupled to a large quantum dot being the finite size reservoir. Different experiments performed in the strong inter-dot coupling limit will confront us to the multi level nature of the large quantum dot where hybridization of both objects has to be carried over several energy levels. In particular, we observe a lifting of Coulomb blockade at the double dot charge degeneracy point. We show that a Kondo mechanism through a hybridized double-dot state is at the origin of the transport process. The associated Kondo temperature is boosted due to the reduction of the charging energy of the system. Surprisingly, the lifting appears to be independent of the large dot occupation number. We relate this observation to a reduction of the exchange interaction between the dots due to the small energy level splitting in the large dot.

9h50 **I. Burmistrov** **Spin and Charge Correlations in Quantum Dots: An Exact Solution**

The inclusion of charging and spin-exchange interactions within the Universal Hamiltonian description of quantum dots is a highly non-trivial problem owing to the fact that it leads to a formulation of the problem in terms of a non-Abelian action. We present an exact analytical solution of the probem, in particular, in the vicinity of the Stoner instabilty point. We calculate several physical observables, including the tunneling density of states (TDOS) and the spin susceptibility [1]. Due to the presence of spin-exchange interaction, at the vicinity of the instability point the TDOS exhibits a non-monotonous behavior as function of the tunneling energy. This effect survives even at temperatures higher than the exchange energy. Our results for the spin susceptibility and TDOS are extended to the presence of the Zeeman splitting [2]. Our approach is generalizable to a broad set of observables, including the a.c. susceptibility and the absorption spectrum for anisotropic spin interaction. Experimentally, our results could be tested in nearly ferromagnetic materials. This analysis is a first step towards solving more complicated problems of transport in quantum dots with spin-exchange interaction, addressing such effects as level statistics at low temperatures, superconducting fluctuations, and non-equilibrium conditions. This work has been done in collaboration with Yuval Gefen (Weizmann Institute, Israel) and Mikhail Kiselev (ICTP, Italy). [1] I.S.Burmistrov, Yuval Gefen, and M.N. Kiselev, JETP Lett. 92, 179 (2010) [2] I.S. Burmistrov, Yuval Gefen, M.N. Kiselev, in preparation.

10h20	**Y. Kanai**	**Superconducting transport at spin singlet-triplet degeneracy in a self-assembled InAs quantum dot Josephson junction** For a quantum dot (QD) strongly coupled to superconducting electrodes Josephson current is generally observed when the dot has an even number of electrons. On the other hand, for a dot with an odd number of electrons it is less pronounced but can be enhanced in case the spin-1/2 Kondo effect is sufficiently strong that the Kondo temperature is larger than the superconducting gap[3]. In this work we first study the interplay between the superconductivity and Kondo effect for a dot with an even number of electrons. In such a QD two electrons residing in the highest occupied levels form either a singlet or triplet state depending on the relative magnitude of the exchange interaction and the single-particle energy level separation[1]. The Kondo effect appears pronounced when the singlet and triplet states are degenerate (S-T Kondo)[2]. We use a self-assembled InAs QD directly connected to the superconducting leads to measure the superconducting transport for the QD in the single! t ground state and near the S-T degenerate point. The QD has a laterally-coupled sidegate as well as a backgate. By changing both gate voltages, we are able to tune the ground state between the singlet state and triplet state and observe the S-T Kondo effect near the transition point. In these regions we observe the superconducting transport. A sharp zero-bias conductance peak or Josephson current is observed in the singlet ground state and Kondo regions but not in the triplet state. Also we observe the enhancement of the first order Andreev reflection in the S-T Kondo regime. References [1] S. Tarucha et al., PRL 84, 2485 (1999). [2] S. Sasaki et al., Nature 405, 764 (2000) [3] Y. Kanai et al., PRB 82, 054512 (2010)
10h50	**D. Weinmann**	**What Is Measured in the Scanning Gate Microscopy of a Quantum Point Contact?** Watching electrons go by is one of the most fascinating issues of Quantum Mechanics. Attempting such an experiment in a solid-state environment, like in a two-dimensional electron gas, involves subtle ingredients such as decoherence and many-body effects, as well as cross-talks and other technical limitations. The conductance changes measured under the influence of a local perturbation (e.g. Scanning Gate Microscopy, SGM) have been interpreted as a mapping of the electron current density in a nanostructured device. In agreement with the dictates of Quantum Mechanics, our perturbative analysis shows that the SGM measurements in a phase-coherent nanostructure are not given by a local quantity, but by two scattering states impinging from opposite electrodes [1]. In the case of a Quantum Point Contact (QPC) exhibiting conductance quantization, the first-order contribution for weak tip voltages is significant only on the conductance steps, while the second-order correction is the dominant one on the plateaus. The latter contribution is always negative, exhibits fringes, and has a spatial decay consistent with SGM experiments on QPC. [1] “What Is Measured in the Scanning Gate Microscopy of a Quantum Point Contact?” R.A. Jalabert, W.Szewc, S. Tomsovic, and D. Weinmann, Phys. Rev. Lett. 105, 166802 (2010)
11h20		**Closing Moriond 2011 "Quantum Mesoscopic Physics"**
11h30	Lunch	
12h00		Bus departure to Geneva (Train station & Airport)

Poster 1:

Mesoscopic transport in Graphene and Carbone Nanotubes, and topological insulators

G. Albert

Conductance fluctuations in Superconductor/Graphene/Superconductor junctions

Graphene exhibits several signatures of coherent transport, such as Universal Conductance Fluctuations (UCF) [1], and the Josephson Effect when connected to superconducting electrodes [2]. This work focuses on the interplay between these two phenomena. Superconducting Pd/Al electrodes were deposited onto monolayer graphene obtained by mechanical exfoliation of graphite on a Si/SiO2 substrate, which is used as an electrostatic gate to control the carrier density in the sample. The current-voltage characteristics of the Superconductor/Graphene/Superconductor (SGS) junction have been measured at low temperature down to 50 mK. In the normal state of the electrodes (T > Tc = 500 mK), reproducible fluctuations of magnitude ~e?/h are observed in the conductance versus gate voltage curve, in addition to the usual V-shape due to the modulation of the carrier density. The universal character of these fluctuations was confirmed by additional Weak Localization measurements on samples with normal electrodes. In the superconducting state (T < Tc), the differential conductance curves versus bias voltage show Multiple Andreev Reflection patterns, revealing a good interface transmission of the charge carriers. At high carrier density, these patterns are accompanied by the Josephson Effect. At low carrier density, the Josephson Effect is suppressed, thus allowing the observation of UCF. A detailed study of UCF versus temperature reveals that their amplitude is increased by a factor 2 below Tc. Therefore, the superconducting coupling between the electrodes in SGS junctions can be tuned by the gate voltage. In the weak coupling regime, UCF are still present and amplified by the proximity effect of superconducting electrodes. [1] H. B. Heersche, et al., Nature 56, 446 (2007). [2] D.W. Horsell, et al., Solid State Comm. 149, 1041 (2009).

H. Aurich

Permalloy-based carbon nanotube spin-valve

We demonstrate that permalloy (Py), a widely used Ni/Fe alloy, forms contacts to carbon nanotubes (CNTs) that meet the requirements for the injection and detection of spin-polarized currents in carbon-based spintronic devices. We establish the material quality and magnetization properties of Py strips in the shape of suitable electrical contacts and find a sharp magnetization switching tunable by geometry in the anisotropic magnetoresistance (AMR) of a single strip at cryogenic temperatures. In addition, we show that Py contacts couple strongly to CNTs, comparable to Pd contacts, thereby forming CNT quantum dots at low temperatures. These results form the basis for a Py-based CNT spin-valve exhibiting very sharp resistance switchings in the tunneling magnetoresistance, which directly correspond to the magnetization reversals in the individual contacts observed in AMR experiments [1]. We will discuss the electrical gate-tunability of the spin-valve effect in CNT devices and elaborate how the use of Py as the ferromagnetic material in low-dimensional planar spin-active CNT devices might allow one to tap into the rich resources of modern nanomagnetism [2,3]. [1] H. Aurich et al., APL 97, 153116 (2010) [2] S.S.P. Parkin et al., Science 320, 190 (2008) [3] A.K. Patra et al., PRB 82, 134447 (2010)

A. Fay

electron-electron and electron-phonon interactions in graphene

We have investigated the electron-electron (e-e) and electron-phonons (e-ph) interactions in graphene by mean of two different experiments [1]. In both experiments, the electronic temperature in graphene is probed and used to indirectly extract informations on the e-e and e-ph interactions. In the first experiment, a superconductor-graphene-superconductor (SGS) junction is used as an electronic thermometer. An other junction made on the same graphene sheet is current biased to heat up the electrons from 70 mK up to 600 mK, which heating is noticed by a drop of the critical current in the first SGS junction. By resolving the Boltzmann equation with the e-e and e-ph scattering kernels, we find that at equilibrium the input power is mainly entirely transmitted to the superconducting leads. The deduced characteristic e-e interaction time is estimated on the order of 10 fs close to the theoretical calculations [2]. The second experiment concerns the shot-noise and conductance measurements at high bias voltage (~1V) of monolayer (MLG) and bilayer (BLG) graphene samples in a two terminal configuration, at 4 K. Assuming a diffusive transport model, the electronic temperature Te is proportional to the product of the Fano factor F with the voltage V. The electronic temperature dependence of the Joule power shows a clear behavior transition at ~100 K. Above this cross-over temperature, we show that the electrons interact mainly with the optical phonons [3]. This electron-optical phonons interaction is also visible in the conductance which drops down at high bias voltage. In the low temperature regime, we find a T^2 dependence of the power as expected theoretically in the hot-electron regime. [1] A. Fay et al., to be submitted. [2] A. H. Castro Neto, N. M. R. Peres, K. S. Novoselov and A. K. Geim, Rev. Mod. Phys. 81, 109 (2009). [3] J. K. Viljas and T. T. Heikkil?, Phys. Rev. B 81, 245404 (2010).

M. Feigelman **Anomalous Josephson Current via Majorana Bound States in Topological Insulators**

F. Freitag **Spontaneous gap formation in suspended bilayer graphene**

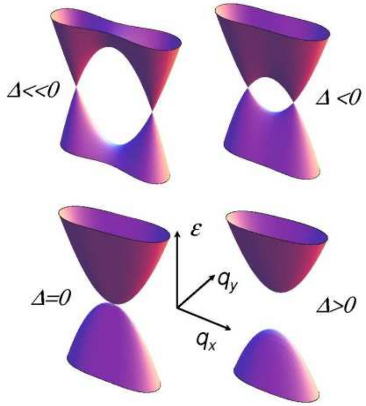
Bilayer graphene has attracted the attention of the research community due to its potential of opening a gap in electron transport and its eightfold-degenerate zero-energy Landau level. We show that suspended bilayer graphene devices allow for a spontaneous gap at zero magnetic field. The properties of this gap are investigated by means of electronic transport in magnetic field, with applied electric bias and as a function of temperature. We find a minimum conductance of about 0.2 e^2/h at the charge neutrality point at 230 mK, independent of the applied magnetic field. Bias measurements show a gap size of 2.5 meV which stays open for temperatures of up to 4 K. Quantum Hall measurements reveal the fully lifted degeneracy of the zero-energy Landau level.

A. K. Huettel **CN-superconductor hybrid devices: Inelastic subgap cotunnelling in a Nb-contacted nanotube quantum dot**

K. Hüttel, T. Geiger, D. Schmid, K. Kang, and Ch. Strunk Hybrid devices combining superconducting leads with carbon nanotubes allow access to a rich field of physical phenomena, as well as a wealth of coherent superconducting circuit technology [1]. We present transport measurements on a SWCNT quantum dot with high quality Nb contacts (Tc = 8.5K, Bc = 4.5T in parallel field). Clear signatures of the superconductivity in the leads are found: over a wide gate range superconductivity-enhanced elastic cotunneling features are observed at an energy of twice the superconducting gap, cf. [2].

In addition, we observe distinct sub-gap features at certain degeneracy points, with a non-monotonic temperature dependence: with just precursors visible close to base temperature, a rich structure of likely Andreev reflection (AR) features develops much more prominently at a few hundred mK. Temperature and magnetic field dependence are discussed in detail. Additional ongoing work focusses on the mechanical properties of ultra-clean carbon nanotube resonators. Here induced superconductivity and superconducting support electronics are to be combined to coherent nano-electromechanical systems in the Gigahertz regime. [1] S. De Franceschi et al., Nature Nanotechn. 5, 703 (2010). [2] K. Grove-Rasmussen et al., Phys. Rev. B 79, 134518 (2009).

G. Montambaux



Motion and merging of Dirac points in two-dimensional crystals

We study under which general conditions a pair of Dirac points in the electronic spectrum of a two-dimensional crystal may merge into a single one. The merging signals a topological transition between a semi-metallic phase and a band insulator. At the transition, the spectrum has the remarkable property to be linear in one direction and quadratic in the other direction. We derive a universal Hamiltonian that describes the vicinity of the transition, characterized by three parameters, a mass, a velocity and a driving parameter Delta whose values are related to the band parameters of any 2D crystal with time-reversal and inversion symmetries. This model describes continuously the coupling between valleys associated with the two Dirac points, when approaching the transition Delta=0. We calculate thermodynamic quantities. The spectrum in the vicinity of the topological transition is very well described by a semiclassical quantization rule. The universal Hamiltonian is applied to the description of graphene-like structures. It reproduces analytically the low field part of the Rammal-Hofstadter spectrum for the honeycomb lattice, when one hopping integral is varied. We discuss the existence of such a merging of Dirac points in graphene-like structures, in the organic salt (BEDT-TTF)2I3 or in optical lattices of cold atoms.

I. Petkovic

High frequency response of graphene monolayers in the Quantum Hall regime

I. Petkovic, F.I.B. Williams, P. Roche, F. Portier, K. Bennaceur, and D.C. Glattli Service de Physique de l?Etat Condens?/IRAMIS/DSM (CNRS URA 2464), CEA Saclay, F-91191 Gif-sur-Yvette, France We study the electronic magnetotransport in graphene at rf frequencies in the few GHz to ~ 50GHz range to investigate the dynamics of charge carriers in the quantum Hall regime. The graphene sample is placed in a break made in a coplanar waveguide and the transmitted power is measured. In order to isolate the response of the sample from the direct transmission between the input and output waveguides, the graphene electron density distribution is modulated with a side gate and the resulting modulation in the transmitted power detected via a standard lock-in technique. The fixed frequency graphene response as a function of magnetic field reveals two different components. One is symmetric in B and dominates under large side gate voltage, and the other shows reproducible fluctuations revealed only at low gate voltage modulation amplitude. The first part is thought to be related to the bulk conductivity and the fluctuations to the carrier dynamics close to the edge. Interestingly, the amplitude of the fluctuations depends on the trajectory of the carriers, since the parity with respect to magnetic field reversal is not conserved. We thus demonstrate the chiral nature of the transport. We speculate that the fluctuations of impedance originate in the scattering from localized states close to the edge of the sample.

C. Quay

Observation of Individual Andreev Bound States in a Carbon Nanotube

When two superconductors are connected by a ?weak link?, a supercurrent can flow between them even if the link is itself not intrinsically superconducting. This phenomenon, known as the Josephson effect, has been observed in a large variety of coherent nanostructures with weak links ranging from molecules and nanowires to tunnel barriers, metallic layers and atomic contacts. Remarkably, a single concept enables us to understand the behaviour of all these devices, that of Andreev bound states (ABS), first conceived of more than four decades ago. We present the first direct spectroscopic observation of individually-resolved ABSs, in devices with carbon nanotubes as weak links. We find that the ABSs arise in this case from the discrete energy levels of the nanotube; our measurements thus constitute a powerful new spectroscopic technique capable of elucidating the electronic structure of nano-structured devices well-coupled to their leads.

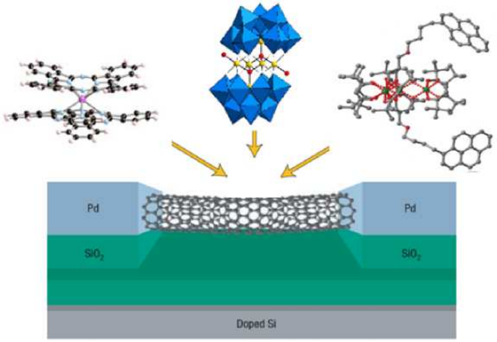
D. Sanchez

Kramers polarization in strongly correlated carbon nanotube quantum dots

Ferromagnetic contacts put in proximity with carbon nanotubes induce spin and orbital polarizations. These polarizations affect dramatically the Kondo correlations occurring in quantum dots formed in a carbon nanotube, inducing effective fields in both spin and orbital sectors. As a consequence, the carbon nanotube quantum dot spectral density shows a four-fold split SU(4) Kondo resonance. Furthermore, the presence of spin-orbit interactions leads to the occurrence of an additional polarization among time-reversal electronic states (polarization in the time-reversal symmetry or Kramers sector). Here, we estimate the magnitude for the Kramer polarization in realistic carbon nanotube samples and find that its contribution is comparable to the spin and orbital polarizations. The Kramers polarization generates a new type of effective field that affects only the time-reversal electronic states. We report new splittings of the Kondo resonance in the dot spectral density which can be understood only if Kramers polarization is taken into account. Importantly, we predict that the existence of Kramers polarization can be experimentally detected by performing nonlinear differential conductance measurements. We also find that, due to the high symmetry required to build SU(4) Kondo correlations, its restoration by applying an external field is not possible in contrast to the compensated SU(2) Kondo state observed in conventional quantum dots.

M. Urdampilleta

Molecular quantum spin valve based on terbium nanomagnets and carbone nanotube



M. Urdampilleta,1 J.-P. Cleuziou,1 N.-V. Nguyen,1 S. Klyatskaya,2 M. Ruben,2,3 W. Wernsdorfer1,* 1 Institut Néel, assosié ? l?Université Joseph Fourier, CNRS, BP 166, 38042 Grenoble Cedex 9, France. 2 Institute of Nanotechnology, Karlsruhe Institute of Technology (KIT), 76344 Eggenstein-Leopoldshafen, Germany. 3 IPCMS, CNRS-Université de Strasbourg, 67034 Strasbourg, France. Molecular quantum spintronics is an emergent field linking the principles from spintronics, molecular electronics and quantum information processing. On the one hand, molecular nanomagnets (MNM) are promising candidates for single spin experiments due to their exciting properties : large spin ground states, strong magnetic anisotropies, quantum tunneling and quantum interference, and long coherence times [1]. On the other hand, carbone nanotube quantum dots (QD) are a very interesting platform to deal with spins, notably because their very long spin coherence length [2]. We developed an original device geometry based on a three terminal carbone nanotube QD, laterally coupled to several MNMs [3]. The latters act on the conduction electron through the QD as spin polarizer and analyzer. This spin-valve effect gives access to the behavior of a single localized spin by standard electrometry. The considered molecule is a pyrenyl-substituted heteroleptical bis-(phthalocyaninato) Terbium(III) complexe, its magnetic properties are well known in the crystal form [4] but also as monolayers on surfaces [5]. Here we report a full characterization of a single Terbium molecule. In particular, we show for the first time stochastic tunneling between entangled electronic and nuclear spin states [3]. [1] Wernsdorfer, W. & Sessoli, R. Science 284, 133-135 (1999). [2] K. Tsukagoshi, B.W. Alphenaar, H. Ago, Nature (London) 401, 572 (1999) [3] Bogani L. and Wernsdorfer W. Nature Mat. 7, 179 - 186 (2008), M. Urdampilleta, J.-P. Cleuziou, S. Klyatskaya, M. Ruben, W. Wernsdorfer, to be submitted. [4] Ishikawa, N., Sugita, M. & Wernsdorfer, W. Angew. Chem. Int. Ed. 44, 2931-2935 (2005) [5] 1. Margheriti L, Chiappe D, Mannini M, et al. Advanced materials. 2010:1-6.

M. Weiss — **Gate Tunable Split-Kondo Effect in a Carbon Nanotube Quantum Dot**

We show a detailed investigation of the split Kondo effect in a carbon nanotube quantum dot with multiple gate electrodes. It is found that the splitting decreases for increasing magnetic field, to result in a recovered zero-bias Kondo resonance at finite magnetic field. Surprisingly, in the same charge state, but under different gate-configurations, the splitting does not disappear for any value of the magnetic field, but we observe an avoided crossing of two high-conductance lines. We think that our observations can be understood in terms of a two-impurity Kondo effect with two spins coupled antiferromagnetically. The exchange coupling between the two spins can be influenced by a local gate, and the non-recovery of the Kondo resonance for certain gate configurations is explained by the existence of a small antisymmetric contribution to the exchange interaction between the two spins.

Qubits with Cavity Quantum Electrodynamics circuits Quantum entanglement with itinerant charge and spins, atoms on chips

J. Rech — **Measurement back-action on adiabatic coherent electron transport .**

We study the back-action of a nearby measurement device on electrons undergoing coherent transfer via adiabatic passage (CTAP) in a triple quantum dot system. The measurement is provided by a quantum point contact capacitively coupled to the middle dot, thus acting as a detector sensitive to the charge configuration of the triple-well system. We account for this continuous measurement by treating the whole {triple-well + detector} as a closed quantum system. This leads to a set of coupled differential equations for the density matrix of the enlarged system which we solve numerically. This approach allows to study a single realization of the measurement process while keeping track of the detector output, which is especially relevant for experiments. In particular, we find the emergence of a new peak in the distribution of electrons that passed through the point contact. As one increases the coupling between the middle dot and the detector, this feature becomes more prominent and is accompanied by a substantial drop in the fidelity of the CTAP scheme.

R. Whitney — **Enhancing coherent oscillations with dissipation at a Landau-Zener crossing.**

The coupling of a quantum system to its environment causes dissipation in the system; this is expected to suppress the coherent oscillations of superpositions of system states (as the superpositions decohere into mixed states). Here we consider coherent quantum oscillations generated by sweeping the system through a Landau-Zener avoided-crossing. Remarkably, we find that weak-coupling to a high-frequency (e.g.~super-Ohmic) environment can strongly enhance such quantum oscillations. Under certain conditions, the coherent oscillations also grow as temperature is increases. This effect should be observable in many quantum systems; such as solid-state qubits, molecular magnets, or polarized neutrons. Reference: R.S. Whitney, M. Clusel and T. Ziman, manuscript in preparation.

Quantum dynamics, High frequency and time dependent phenomena, charge manipulation, quantum shot noise and full counting statistics

J. Basset — **Emission and Absorption quantum noise measurement with an on-chip resonant circuit**

Using a quantum detector, a superconductor-insulator superconductor junction, we probe separately the emission and absorption noise in the quantum regime of a superconducting resonant circuit at equilibrium. At low temperature the resonant circuit exhibits only absorption noise related to zero point fluctuations whereas at higher temperature emission noise is also present. By coupling a Josephson junction, biased above the superconducting gap, to the same resonant circuit, we directly measure the noise power of quasiparticles tunneling through the junction at two resonance frequencies. It exhibits a strong frequency dependence, consistent with theoretical predictions. Ref : J.Basset, H.Bouchiat and R.Deblock, Phys. Rev. Lett. 105, 166801 (2010).

C. Bergenfeldt **Electron transport and fluctuations through microwave cavity coupled quantum dots.**

We investigate theoretically the electronic transport through quantum dots coupled via transmissionline microwave cavities [1] C. Bergenfeldt, P. Samuelsson, in prep. . Within the framework of circuit quantum electrodynamics we derive a cavity-dot Hamiltonian for arbitrary strong coupling between the dot and the cavity. The dots are tunnel coupled to electronic reservoirs and the coherent dynamics of both the dot charge and cavity photons is described by a quantum master equation. The full statistics of the transferred electrons is investigated, with the focus on non-local current and cross-correlation effects. Both few-level dots and metallic dots, that is, single-electron transistors, are described by the theory. We find that the Coulomb-blockade in one of the dots can be lifted by tuning the voltage between the reservoirs coupled to the other dot. We also find a positive cross-correlation between the currents through each of the two dots. We attribute these effects to to single or multiple photon excitation and deexciattion by tunneling electrons into and out of the two dots.

J-M.Berroir **Experimental and theoretical study of the short time current fluctuations of an on-demand single electron emitter.**

This poster will present first the new and original experimental setup [1] developed to measure current fluctuations at GigaHertz frequencies and its use to characterize a recently introduced single electron emitter [2,3]. The setup relies on the combination of an interferometric amplification scheme and a quarter-wave impedance transformer, allowing the measurement of noise power spectral densities with GHz bandwidth up to five orders of magnitude below the amplifier noise floor. We simultaneously measure the high frequency conductance of the sample by derivating a portion of the signal to a microwave homodyne detection. This setup reaches a sensitivity of about 2 10^(-28) A^2/Hz/sqrt(Hz) (1.15 10^(-29) A^2/Hz in five minutes of measurement time) and a stability over 40 hours. Finally, the theoretical tools [3,4] used to analyze these high frequency noise measurements in the context of single electron emitters will also be discussed in details. Comparisons with experimental results will also be presented. [1] F.D. Parmentier et al., A high sensitivity ultra-low temperature RF conductance and noise measurement setup, to be published in Review of Scientific Instruments. [2] G. Fève et al., Science 316, 1169 (2007). [3] A. Mahé et al., Phys. Rev. B 82, 201309 (2010). [4] M. Albert et al., Phys. Rev. B 82, 041407 (2010).

I. Chernii **Direct access to the quantum non-Gaussian noise through the cross-correlation measurements**

The measurement of the effects of quantum non-Gaussian fluctuations is often difficult since they are dominated by the classical Gaussian noise, or require high-frequency amplifiers to be used. In our work we investigate the possibility to employ the cross-correlation technique in order to bypass the aforementioned difficulties. We consider a pair of two-level detectors weakly coupled to the source of fluctuations by means of fast electric circuit. Then we propose that the cross-correlation of the outputs of these detectors is measured. It appears that the contribution of the second order correlations is suppressed and the constant characterizing the third order non-commutative correlations is revealed. Since the coupling is weak, the induced transitions in the detectors can be arbitrarily rare, thus allowing to perform the long-time measurements. However, besides the coupling constant there is an interesting hierarchy of important energy scales related to the properties of the noise, the circuit and the detectors. In order to estimate the resulting cross-correlations we examine the evolution of the system in the fourth order of the perturbation theory. This requires some discretion to keep track of the ordering in the subspaces of the fluctuating field and the degrees of freedom of the detectors. Thus these calculations can also represent some interest from the technical point of view.

P. Hakonen — **Negative resistance quantum amplifier based on minimally damped Josephson junction**

Near quantum limited amplification at microwave frequencies is of basic importance to fundamental quantum mechanics research and sensitive measurements. The fundamental lower limit for the noise temperature of phase-preserving amplifiers at frequency $\omega/2\pi$ is the standard quantum limit given by the noise temperature $T_q = \hbar\omega/2k_B$. In the microwave range the best candidates so far have been amplifiers based on superconducting quantum interference devices (SQUIDs) and non-degenerate Josephson parametric amplifiers reaching noise temperatures from $T_n = 0.5\hbar\omega/k_B$ to $T_n = 2.0\hbar\omega/k_B$ at frequencies between 500 MHz and 8 GHz. We have developed a new type of an amplifier based on a single Josephson junction embedded in the circuitry in such a way that the gain follows directly from the negative real part of its dynamic impedance. The first measurements yield a noise temperature of $T_n = 1.6\hbar\omega/k_B$ at the frequency of 2.8 GHz, already comparable with the state of the art. For the theoretical understanding of this amplifier, noise analysis has to be done beyond the regular Langevin-sourced resistively and capacitively shunted junction description. Self-organization effects are found to be important in the steady-state operation at large gain.

N. Roch — **Information Processing at the Quantum Limit**

Mesoscopic physicists can now create quantum systems whose symmetries and energy levels are externally controlled by macroscopic quantities such as voltage, current, magnetic eld... Moreover the coherence time of these articial atoms increased so much over the last decade that they match the purity of actual atoms in Quantum optics. We are hence close to making quantum machines. Toward this path, we still need to perform an accurate and continuous state measurement. Most measurement apparatus use microwaves photons. Performing a continuous measurement implies working at the single or so photon level. The best commercially available ampliers add at best 10 photons of noise to the signal. This is far from the limit set by quantum mechanics which is half a noisy photon for a phase-sensitive amplier. We have developed a mesoscopic amplier based on a ring of four Josephson junctions : the Josephson Ring Modulator. It is the rst practical implementation of a phase preserving parametric amplier which could reach the quantum limit. Besides, it also naturally generates quantum correlated pairs of photons with different wavelength during the amplication of the signal. This amplier will allow us to explore many quantum properties : observing a quantum trajectory, performing a weak measurement of a quantum object and nally improving the coherence by quantum feedback.

FQHE and abelian/non-abelian topological excitations, electronic correlations in low D, 0.7 anomaly.

T. Champel — **Nonlocal correlations of the local density of states in disordered quantum Hall systems**

Motivated by recent high resolution scanning tunneling microscopy (STM) experiments in the quantum Hall regime both on massive two-dimensional electron gas and on graphene, we consider theoretically the disorder averaged non-local correlations of the local density of states (LDoS) for electrons moving in a smooth disordered potential in the presence of a high magnetic field. The intersection of two quantum cyclotron rings around the two different positions of the STM tip, correlated by the local disorder, provides peaks in the spatial dispersion of the LDoS-LDoS correlations when the inter-tip distance matches the sum of the two quantum Larmor radii. The energy dependence displays also complex behavior: for the local LDoS-LDoS average (i.e., at coinciding tip positions), sharp positive correlations are obtained for tip voltages near Landau levels, and weak anticorrelations otherwise.

C. Grenier	**Decoherence and relaxation of a source of minimal electronic excitations in quantum Hall edge channels** P. Degiovanni (1), Ch. Grenier(1), G. Fève (2) (1) Laboratoire de physique de l'ENS Lyon, 46 Allée d'Italie, 69364 LYON Cedex 07 (2) Laboratoire Pierre Aigrain, Département de physique de l'?cole Normale Supérieure, 24 rue Lhomond, 75005 PARIS In [1], the authors proposed a setup dedicated to single electron emission in a quantum Hall edge channel with minimal electron/hole pair production. This proposition did not rely on electron confinement [2] but suggested to generate a coherent plasmonic state by the mean of a Lorentzian voltage pulse of quantized action. In this communication, we propose to discuss how interactions affect the single particle coherence issued by such a source realized as an Ohmic contact driven by a periodic train of Lorentzian pulses.Two limiting behaviours depending on the driving frequency have been identified?: At low driving frequency, interactions are responsible for a quantitative change in the single particle coherence When the driving frequency increases, quasiparticle relaxation is blocked by the Pauli principle and the single particle coherence is left untouched, a result coherent with previous studies [3]. Predictions are made for the experimental signal expected for noise measurements in a Hanbury-Brown Twiss configuration [4]. [1] J. Keeling, I. Klich, and L. S. Levitov Phys. Rev. Lett. 97, 116403 (2006) [2] G. Fève, et al., Science 316 1169 (2007) [3] P. Degiovanni, et al., Phys. Rev. B 80, 241307 (2009) [4] . Grenier , . Hervé,E. Bocquillon, F. D. Parmentier, B. Pla?ais , J.-M. Berroir, G. Fève & P. Degiovanni,'Single electron quantum tomography in quantum Hall edge channels', http://arxiv.org/abs/1010.2166.
T. Martin	**Poissonian tunneling through an extended impurity in the quantum Hall effect** We consider transport in the Poissonian regime between edge states in the quantum Hall effect. The backscattering potential is assumed to be arbitrary, as it allows for multiple tunneling paths. We show that the Schottky relation between the backscattering current and noise can be established in full generality: the Fano factor corresponds to the electron charge (the quasiparticle charge) in the integer (fractional) quantum Hall effect, as in the case of purely local tunneling. We derive an analytical expression for the backscattering current, which can be written as that of a local tunneling current, albeit with a renormalized tunneling amplitude which depends on the voltage bias. We apply our results to a separable tunneling amplitude which can represent an extended point contact in the integer or in the fractional quantum Hall effect. We show that the differential conductance of an extended quantum point contact is suppressed by the interference between tunneling paths, and it has an anomalous dependence with respect to the bias voltage.

Poster 2:

Mesoscopics of hybrid systems: superconducting/ferro/Normal/Kondo

Y. Avishai

Broken Time-reversal Symmetry in Multiband Superconductor Josephson coupling through an Anderson impurity

A Josephson junction consisting of two-band and single-band superconductors weakly coupled to each other through an Anderson impurity exposes a time reversal breaking ground state when the coupling between the two bands exceeds a certain threshold. The critical regime occurs around local moment formation. This indicates a fundamental and distinct role of strong correlations: Driving a system into a time reversal breaking ground state. One of the observable consequences is that the impurity magnetization in this phase is reduced.

L. Bretheau

Quasiparticle poisoning of Andreev states in superconducting atomic-contacts

We have measured the supercurrent through phase-biased superconducting atomic contacts, which are simple but generic Josephson weak links containing just a few conduction channels. We find that, under certain conditions, the supercurrent through a well-transmitting conduction channel vanishes completely. This is interpreted as the result of ?poisoning? by a single quasiparticle trapped in the Andreev bound states of the channel. We present a detailed characterization of the dynamics of trapping and untrapping. Poisoning can have important consequences for both the implementation of Q-bits based on Andreev levels, and the search for Majorana states predicted to arise at the interface between a superconductor and a topological insulator for example. Work done in collaboration with: Q. Le Masne, M. Zgirski, H. Pothier, D. Esteve and C. Urbina.

T. Capron

Universal Conductance Fluctuations and Spin Glasses

Spin glass is one of the most fascinating states of matter, in which the magnetic disorder is randomly quenched. As a model system for glasses in general, it has been extensively studied, both theoretically and experimentally. All this work has converged towards two main descriptions of the fundamental state of the system that are clearly antagonist. On the one hand, the "mean-field" solution leads to a ground state consisting in multiple states organized in a hierarchical structure. On the other hand, the magnetic "droplet" model is based on the off-equilibrium dynamics of a unique ground state. However the experimental validation of one of these theories requires a detailed observation of the sample at the microscopic level. Mesoscopic physics proposes a unique tool to access this microscopic configuration of the impurities: the universal conductance fluctuations (UCF) which represent a fingerprint of the magnetic disorder of the sample. This could allow to measure the spin overlap Q and thus the spin glass order parameter. We present the implementation of universal conductance fluctuations measurement in AgMn spin glass wires. We show that UCF measurements allow to probe both the magnetic excitations of the system and the order parameter of the spin glass. [1] B. Al'tshuler and B. Spivak, JETP Lett. 42, 447 (1985) [2] P. de Vegvar, L. P. Lévy and T. Fulton, Phys. Rev. Lett. 66, 2380 (1991) [3] D. Carpentier and E. Orignac, Phys. Rev. Lett. 100, 057207 (2008) [4] T. Capron et al. to appear in Europhys. Lett.

D. Chevallier

Current and noise correlations in a double dot Cooper pair beam splitter.

We consider a double quantum dot coupled to two normal leads and one superconducting lead, modeling the Cooper pair beam splitter studied in two recent experiments. Starting from a microscopic Hamiltonian we derive a general expression for the branching current and the noise crossed correlations in terms of single and two-particle Green's function of the dot electrons. We then study numerically how these quantities depend on the energy configuration of the dots and the presence of direct tunneling between them, isolating the various processes which come into play. In absence of direct tunneling, the antisymmetric case (the two levels have opposite energies with respect to the superconducting chemical potential) optimizes the Crossed Andreev Reflection (CAR) process while the symmetric case (the two levels have the same energies) favors the Elastic Cotunneling (EC) process. Switching on the direct tunneling tends to suppress the CAR process, leading to negative noise crossed correlations over the whole voltage range for large enough direct tunneling.

S. Csonka **Cooper pair splitter realized in a two-quantum-dot Y-junction**

An important step towards the realization of solid state based quantum computer is the demonstration of entangled spatially separated electrons. During the last years extensive theoretical investigation has been done and different device configurations were suggested. The Cooper-pairs of superconductors are a natural source of spin entangled electrons, the separation of these electron pairs is the underlying concept of several theoretical proposals [2-4]. In this work we present the first experimental realization of a tunable Cooper Pair Splitter. The device contains a superconducting electrode coupled to two quantum dots, which is fabricated based on InAs Nanowire. In a superconducting beam splitter configuration two basic processes can happen with a Cooper-pair: the two electrons either split up into the two arms of the beam splitter or they leave the device in the same arm. The charging energy strongly suppresses to put two electrons on the same quantum dot, therefore implementing quantum dots into the arms of the beam splitter serves as a filter for the desired splitting process. Performing non-local transport measurements on such devices, we have demonstrated the Cooper-pair splitting process. Furthermore, the separate tunability of the two dots allows studying the splitter efficiency for different settings of the quantum dots' levels. The observed results show unexpected behavior, which is beyond the existing theoretical predictions [1]. [1] L. Hofstetter, S. Csonka, J. Nygard & C. Schonenberger, Nature 461, 963 (2009). [2] P. Recher, E. V. Sukhorukov and D. Loss, Phys. Rev. B 63, 1165314 (2001). [3] G. B. Lesovik, T. Martin and G. Blatter, Eur. Phys. J. B 24, 287 (2001). [4] P. Samuelsson and M. Buttiker, Phys. Rev. Lett. 89, 466011 (2001).

F. Deon **Quantum dot spectroscopy of proximity-induced superconductivity in a two-dimensional electron gas**

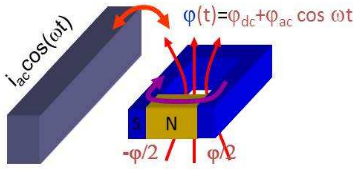
We report the realization of a hybrid superconductor-quantum dot device by means of top-down nanofabrication starting from a two dimensional electron gas in a InGaAs/InAlAs semiconductor heterostructure. The quantum dot is de?ned by electrostatic gates placed within the normal region of a planar Nb-InGaAs quantum well-Nb junction. Measurements in the regime of strong Coulomb blockade as well as cotunneling spectroscopy allow to directly probe the proximity-induced energy gap in a ballistic two-dimensional electron gas coupled to superconductors.

A. Geresdi **Transition from coherent mesoscopic single electron transport to proximity Josephson current**

Point contact Andreev reflection is a versatile tool to investigate the properties of a metallic system by using a superconducting tip as a probe. Exploiting the nonlinear current-voltage characteristics of a superconductor ? normal metal hybrid junction, one can obtain physical properties of the normal metal on the nanoscale. We study the variation of the zero bias peak (ZBP) while the contact diameter of a superconductor (Nb) ? degeneratively doped semiconductor ((In,Be)Sb) junction is tuned. Using our custom-built mechanically controlled point-contact system we are able to establish stable junctions from the single atomic regime up to several hundreds of nanometers, therefore I-V characteristics of several distinguished junctions in both the ballistic and diffusive regime were taken. Emergence of the ZBP during the crossover from the ballistic to the diffusive regime is shown, in correspondence with earlier calculations connecting this effect to diffusive transport. Moreover, if we further enhance the contact diameter, we find a marked crossover between the coherent mesoscopic single electron transport and the formation of quasi-bulk proximity superconductivity. This transition is reflected by the appearance of a clear Josephson effect. The Cooper pair formation is observed if both the diameter of the contact and the phase diffusion length defined by the temperature become larger than the thickness of the normal metallic layer resulting in a coherent localized region beneath the point contact effectively resulting in the formation of a SIS? junction. We demonstrate the influence of decoherence factors such as finite temperature, voltage bias and local exchange field on the ZBP, and show that they eventually lead to the destruction of the effect. On this basis, we consider the scheme of diffusive NS junctions as a novel tool to detect local ferromagnetism.

S. Guéron

Dynamics of Andreev pairs in an SNS junctions



When a metallic normal wire connects two superconducting reservoirs, at sufficiently low temperature, a non dissipative current can flow through the junction. If the wire is longer than the superconducting coherence length, the amplitude and temperature decay of this supercurrent only depend on the mesoscopic parameters of the normal wire: phase coherence time and Thouless energy. Whereas the equilibrium properties of such SNS junctions are well understood, high frequency and out of equilibrium physics are still under exploration in order to determine the relevant time scales of phase relaxation. In order to investigate the evolution of the current phase relation in such SNS junctions with high frequency phase driving, we have inductively coupled one NS ring to a multimode superconducting resonator. The in- and out-of-phase ac linear response of the ring is deduced from the dc flux dependence of the frequency and quality factor of the resonances, from 300 MHz to 6 GHz. Whereas the flux dependence of the non dissipative current response is well explained using Usadel equations in the regime of a very long inelastic relaxation time, the large dissipative current response is only explained by introducing a relaxation time of the order of the diffusion time through the normal wire. These results are compared to recent theoretical findings and stimulate future similar investigations on more exotic junctions. Work done in collaboration with F.Chiodi, B. Dassonneville, K. Tikhonov, P. Virtanen, T. Heikkilä, M. Feigelman, M. Ferrier, H.Bouchiat.

D. Gutman

Non-equilibrium 1D many-body problems and asymptotic properties of Toeplitz determinants

Non-equilibrium bosonization technique facilitates the solution of a number of important many-body problems out of equilibrium, including the Fermi-edge singularity, the tunneling spectroscopy and full counting statistics of interacting fermions forming a Luttinger liquid. We generalize the method to non-equilibrium hard-core bosons (Tonks-Girardeau gas) and establish interrelations between all these problems. The results can be expressed in terms of Fredholm determinants of Toeplitz type. We analyze the long time asymptotics of such determinants, using Szeg\H{o} and Fisher-Hartwig theorems. Our analysis yields dephasing rates as well as power-law scaling behavior, with exponents depending not only on the interaction strength but also on the non-equilibrium state of the system.

M. Houzet

Distribution function of persistent current

We introduce a variant of the replica trick within the nonlinear sigma model that allows calculating the distribution function of the persistent current. In the diffusive regime, a Gaussian distribution is derived. This result holds in the presence of local interactions as well. Breakdown of the Gaussian statistics is predicted for the tails of the distribution function at large deviations.

F.Lefloch

Current noise correlations in three terminal diffusive SNS junctions

We present new measurements of current noise cross-correlations in three-terminal diffusive superconductor-normal metal-superconductor (S/N/S) junctions with high transparency. We studied two kinds of devices with closely spaced junctions (~0.5 µm) and well separated junctions (10 µm) both in a wide range of applied bias voltage and temperature. The samples comprising three terminal double SNS diffusive junctions are made of copper as the normal metal and aluminum as superconducting material. Typical length for the normal junctions is ~ 1 µm. The noise correlation measurements spanned from regimes where electron-electron interactions were relevant to regimes of collisionless Incoherent Multiple Andreev Reflection (IMAR). For these measurements, we have set-up a new experimental tool to measure both the noise and the correlations in three terminal devices.

The experiment operates down to 30 mK and is equipped with three commercial SQUID a very sensitive current amplifiers. Each arm of the sample is connected to the input coil of a SQUID.

Whereas the noise cross-correlations were zero in samples with well separated junctions, the sign of the correlations were found to be mostly negative in the IMAR regime for the case of closely spaced junctions.

R. Lopez **Non linear transport relations in a spin-diode**

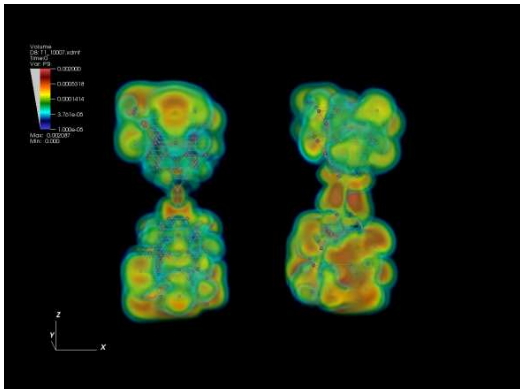
In this work we study the full counting statistics of a spin-diode. We derive the nonlinear transport relations taking into account the spin degree of freedom from general arguments based on the symmetries of the generating function. In our system we consider the effect of a spin-flip term that breaks the validity of detailed balance. Even for this case our system fulfill the nonlinear transport relations. Additionally we show specific transport quantities like the shot noise that becomes superPoisonian under some circumstances.

O. Lysova **Investigation of switching kinetics of ferroelectric nanocrystals and thin films of copolymers by AFM**

Recently the question on definition of the critical size in ferroelectricity became very actual in connection with development ferroelectric nanostructures. One of the most interesting to researches in this area a material are copolymer LB-films viniliden fluoride-triftoretilena P [VDF-TrFE] as they possess ferroelectric properties, and the given way of their preparation allows to receive films in the thickness to one monolayer that is the extremely important for research of effect of critical switching. The Ginzburg-Landau theory with use of the ?mismatch? boundary conditions accounting for various structure of electrodes and a film, foretells that the critical thickness can be very small and in general be absent. For confirmation of this fact, the switching experimental research of nanoscale films and nanocrystalls of ferroelectric copolymer in atomic force microscope has been carried out. In this work the switching kinetics of ferroelectric polymer Langmuir-Blodgett film 70:30 and copolymer nanocrystals was investigated using piezoresponse force microscopy (PFM). The nanocrystals were made by self-organization from Langmuir-Blodgett films of a 70% vinylidene fluoride and 30% trifluoroethylene copolymer. The polarization switching time exhibits an exponential dependence on reciprocal voltage that is consistent with nucleation switching dynamics.

P. Makk **Channel sensitive theoretical and experimental analysis of indium nanojunctions**

For comparison we have calculated hundreds of conductance traces for, where the stochasticity of experimental contact ruptures is mimicked by molecular dynamics simulations, and along the simulated rupture the transport properties ? including the full channel decomposition and wavefunctions (Figure 1) ? are determined by DFT calculations [3]. The shape of the conductance histogram, and also in the evolution of individual channel transmissions shows remarkable correspondence with the experiment. Our analysis clearly shows that importance of simulating the stochasticity of contact ruptures, as the calculations on ideal geometries artificially introduce some special symmetries not being present in experiment. [1] E. Scheer et al., Nature 394, 154 (1998) [2] A. Halbritter, P. Makk et al., Phys. Rev. B. 77 075402 (2008) [3] E. Artacho et al., J. Phys.: Condens. Matter 20, 064208 (2008)



V. Maisi **Andreev tunneling in NIS junctions and SINIS turnstiles**

SINIS turnstile is a prominent device for achieving accurate charge pumping at a level required for the redefinition of electrical SI-units. Our previous studies of the device have shown that it is crucial to suppress environment fluctuations to improve the performance of the device. When the environmentally assisted tunneling is made low enough, the remaining error mechanism for the device is higher order tunneling. Here we present the real-time detection of Andreev tunneling. We have detected these events with an SET electrometer and directly distinguished them from one-electron processes providing a direct proof of their existence and allowing us to measure their rate. Since the rate depends on coherence properties of the wavefunctions of two electrons, it gives a fingerprint of the junction. The tunneling rates we observe indicate that the standard barriers are quite far from being atomically flat insulator layers. In addition, we have determined the influence of the Andreev tunneling to the pumping plateau of the turnstile. With low charging energy, the Andreev tunneling yields excess current through the device. With increased charging energy, the charge quantization improves and then the Cooper pair - electron cotunneling is expected to be the remaining error mechanism which can be made low enough for metrological applications.

F. Parmentier **Strong dynamical Coulomb blockade with coherent conductors**

In mesoscopic circuits, the impedances composition laws differ from their classical counterparts. For instance, the conductance of a coherent conductor embedded in a dissipative circuit is reduced at low energy. This results from the excitation of the circuit's modes by the current pulses associated with charge transfers across the coherent conductor. This quantum phenomenon, known as dynamical Coulomb blockade, is well understood theoretically and has been checked experimentally since the early 90s on the simplest coherent conductors realized by tunnel junctions. More recently, it has been found that if a short coherent conductor is embedded in a circuit of impedance much smaller than the resistance quantum Rk=h/e^2, the dynamical Coulomb blockade corrections, as quantum shot noise, are reduced compared to the case of a tunnel junction by the so-called Fano factor. However, an experimental study of the dynamical Coulomb blockade when these corrections are relatively important was still missing. The present experimental work fills this gap. We use a quantum point contact with a transmission tuned continuously between 0 and 1, as a test-bed for short coherent conductors. When this quantum point contact is inserted in an onchip circuit of impedance comparable to Rk, we observe significant deviations from the Fano factor reduction calculated using the transmission in absence of dynamical Coulomb blockade, and a very good agreement when using the transmission reduced by dynamical Coulomb blockade.

D. Pikulin **Topological properties of superconducting scattering matrices.**

Motivated by recent developments in "topological" superconductors, we study topological properties of s-matrix of superconducting junctions. We argue that for a finite junction the s-matrix is always topologically trivial. Apparent contradiction with previous research is resolved if low-energy resonant poles of s-matrix are taken into account. This suggests that for finite junction a common topological transition does not take place. Instead, we reveal a different topological transition that concerns the configuration of the resonant poles. (work done in collaboration with Yuli Nazarov)

M. Pletyukhov **Real-time renormalization group approach to the time evolution of quantum impurity models**

We address the problem of how a quantum local interacting dissipative system evolves towards nonequilibrium stationary state. Applying the recently established method of real-time renormalization group (RTRG) we study the real-time evolution of observables after a sudden switching of a coupling to reservoirs with chemical potentials +V/2 and -V/2 in two basic models. In particular, we consider the anisotropic Kondo model (both antiferromagnetic and ferromagnetic) and interacting resonant-level model (IRLM) which are the minimal models for the study of spin and charge fluctuations, respectively. We derive analytic expressions for all time scales and find that: 1) all observables (spin, current, dot population) decay with both relaxation and decoherence rates; 2) bias voltage V appears as an important energy scale for the dynamics setting the frequency of oscillatory behavior; 3) the decay is not purely exponential but is rather accompanied by the power-law decay.

V. Pribiag

Spin-orbit qubits in semiconductor nanowires

Authors: S. Nadj-Perge, S. M. Frolov, V. S. Pribiag, J. van den Berg, E. P. A. M. Bakers, and L. Kouwenhoven The spin-orbit interaction provides an efficient handle that enables all-electric control of spins down to the level of single electrons [1]. For indium arsenide nanowires the spin-orbit interaction is sufficiently strong that electrons act as spin-orbit doublets [2,3]. We perform universal rotations of the spin-orbit states of a single electron using microwave-frequency electric fields, thus demonstrating fast, coherent control over a spin-orbit qubit [4]. The qubits, which are confined to single-electron quantum dots along the nanowire, can be addressed individually by means of electrostatic tuning of the local g-factor. We demonstrate enhanced coherence using a Hahn echo scheme and more complex dynamical decoupling pulse sequences. The dominant source of decoherence is consistent with the effects of nuclear spin fluctuations mediated by the hyperfine interaction. To further understand the nuclear dynamics we investigated abrupt, hysteretic switching of the transport curre! nt that occurs when our double-dots are tuned to the Pauli spin blockade regime. Electric-dipole spin-resonance measurements rule out the build-up of considerable nuclear spin-polarization, but are compatible with the build-up of a nuclear spin polarization gradient of a few mT between adjacent dots. Lastly, we will present evidence for non spin-conserving transitions between two strongly-coupled dots that are mediated by the strong spin-orbit interaction. [1] Nowack, K. C., Koppens, F. H. L., Nazarov, Y. V. & Vandersypen, L. M. K. Science 318, 1430?1433 (2007) [2] Fasth, C., Fuhrer, A., Samuelson, L., Golovach, V. N. & Loss, D. Phys. Rev. Lett. 98, 266801 (2007) [3] Pfund, A., Shorubalko, I., Ensslin, K. & Leturcq, R. Phys. Rev. B 76, 161308 (2007) [4] Nadj-Perge, S., Frolov, S. M., Bakkers, E. P. A. M., and Kouwenhoven, L. P. Nature 468, 1084 (2010).

G. Rastelli

Finite Size Effects on Quantum Phase Slips in Josephson Junction arrays

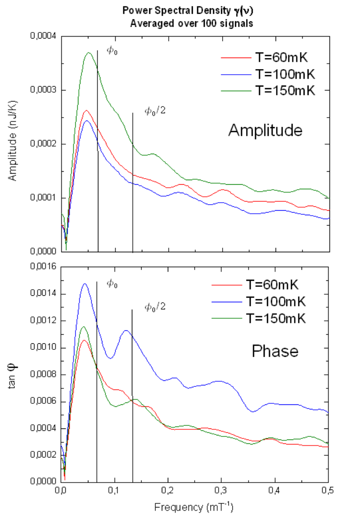
Quantum superconducting circuits realized with one dimensional Josephson junction arrays have received great interest recently [1]. For homogeneous and dissipationless arrays, the electrostatic interactions between the metallic islands suppress the charge quantum fluctuations and, inversely, increase the phase quantum fluctuations (phase-slip). These phase fluctuations can manifest as a remarkable reduction of the critical current flowing through the system [2]. Recent experiments, realized by the experimental group of Grenoble, have confirmed these predictions by varying the Josephson energy of the single junctions[3]. The effective control of the parameters and their tunability in the present experimental devices allow the spanning of different physical regimes with great accuracy. They call for a theoretical analysis which takes into account the actual conditions of the system. Up to now, finite size arrays with N junctions have only been treated in the limit N>>1 [2]. We present a theoretical model describing the finite-size effects on the quantum phase slip mechanism. In particular, we discuss the effects of the discrete electromagnetic modes of the array on the local phase slip processes. The results of the calculations are in good agreement with the experimental observations of the critical current in Josephson junction arrays of different lengths [4]. [1]S. Gladchenko, D. Olaya, E. Dupont Ferrier, B. Dou?ot, L.Ioffe and M.E. Gershenson, Nature Physics 2009. [2]K. A. Matveev, A. I. Larkin, L. I. Glazman, Phys. Rev. Lett. 2002. [3]I. M. Pop, I. Protopopov, F. Lecocq, Z. Peng, B.Pannetier, O. Buisson, W. Guichard, Nature Physics 2010. [4]I. M. Pop, G. Rastelli et all. [unpublished]

I. Sadovskyy

Charging states in an Andeeev quantum dot

A quantum dot connected via tunnel barriers to superconducting leads (Andreev quantum dot) traps a continuously tunable and hence fractional charge. The fractional charge on the island is due to particle-hole symmetry breaking and can be tuned via gate potential acting on the dot or via changes in the phase difference across the island. This charge is very sensitive to the phase and, therefore, to the magnetic flux. This fact allows us to think about new type of magnetometers based on Andreev quantum dots. We study the sensitivity of this device as a function of its parameters in the limit of a large superconducting gap. In our analysis, we account for the effects of weak Coulomb interaction within the dot. We discuss the suitability of this setup as a device for detecting weak magnetic fields.

G. Souche



Thermal signatures of quantum phase coherence in metallic rings

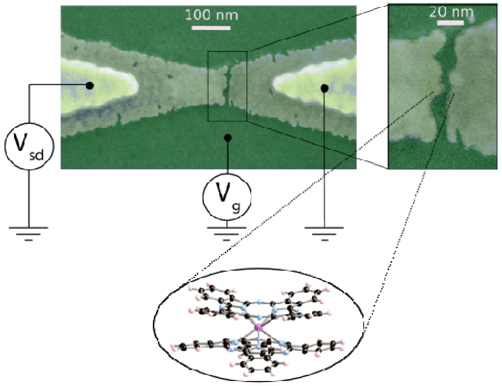
We report very high sensitivity specific heat measurements of normal metal silver rings at very low temperatures. The objective is to measure the possible thermal signatures due to the presence of persistent currents. This phenomenon is still badly understood at low magnetic field, some contradictions existing between experimental results and the currently accepted theories. As theoretically predicted by the model of persistent currents at equilibrium, the specific heat should be periodic with the magnetic flux. A periodicity of Phi0=h/e or Phi0/2 is expected. The expected variation of heat capacity for our samples is estimated to be of 10^-16J/K to 10^-14J/K. We have studied 2x10^6 silver rings patterned on a suspended silicon membrane. We have realized, at three differents temperatures (60,100 and 150 mK), 100 identical scans of heat capacity measurement as a function of the magnetic field. During this experiment, we reached a sensitivity of 9.10^-15J/K. Signal processing based on Fourier analysis has been conducted on the measured heat capacity signals. It gives the spectral density of the signal and permits to detect the frequency associated to an oscillation. This has revealed a peak on the phase of the signal at 0.11 Hz (i.e. 9mT) for the three temperatures. This value corresponds to a Phi0/2 period in flux. The presence of a trend on the raw heat capacity signal could mask the expected peak corresponding to a Phi0 period. The observed peak appears only on the phase signal, not on the amplitude signal. This may be attributed to out of equilibrium signals.

A. Vasenko

Current-voltage characteristics of tunnel Josephson junctions with a ferromagnetic interlayer

We present a quantitative study of the current-voltage characteristics (CVC) of diffusive superconductor/ insulator/ ferromagnet/ superconductor (SIFS) tunnel Josephson junctions. In order to obtain the CVC we calculate the density of states (DOS) in the F/S bilayer for arbitrary length of the ferromagnetic layer, using quasiclassical theory. For a ferromagnetic layer thickness larger than the characteristic penetration depth of the superconducting condensate into the F layer, we find a simple analytical expression which agrees with the DOS obtained from a self-consistent numerical method. We discuss general properties of the DOS and its dependence on the parameters of the ferromagnetic layer. In particular we focus our analysis on the DOS oscillations at the Fermi energy. The corresponding CVC can be used to calculate the macroscopic quantum tunneling (MQT) escape rate for the current biased SIFS junctions by taking into account the dissipative correction due to the quasiparticle tunneling. We show that the influence of the quasiparticle dissipation on the macroscopic quantum dynamics of SIFS junctions is small, which is an advantage of SIFS junctions for superconducting qubits.

R. Vincent



Terbium based single-molecule spin transistor: entanglement of electronic and nuclear spins

The last two decades have seen the emergence of a new field merging the magnetic and electric properties of materials, leading to new ways in storing and processing the information. The miniaturisation of the devices is pushing toward the investigation of the interaction between transport and magnetic properties at a nanometric scale. It has given rise to molecular quantum spintronics [1], which studies the magnetic moment of a single molecule interacting with electrons flowing through a nanostructure. A possible candidate in building such a device is a Single-Molecular Magnet (SMM) based transistor. The choice of SMMs is motivated by their large spin and anisotropy leading to long coherence time. Furthermore, they are subject to quantum phenomenon such as quantum tunneling or Berry phase interference. The first experiments on a Single-Molecule Transistor (SMT) based on SMMs did not show encouraging results [2,3], due to the loss of the magnetic properties because of a strong interaction with the environment. But recent results [4] have shown that the magnetic properties of SMMs could be kept intact if the spin was well protected as it is the case of a bis-(phthalocyaninato) Terbium(III) molecule. These molecules have been studied in details both in monolayers [5] and crystals [6]. Here, we will present our measurements performed on a SMT based on bis-(phthalocyaninato) Terbium(III). We report for the first time the detection, at the single molecular level, of the quantum tunneling of the magnetization of two entangled spins : the electronic magnetic moment of the Terbium entangled with its nuclear spin. This magnetic characterization of a single magnetic spin is successfully performed using the extreme sensitivity of the Kondo regime to its magnetic environment showing how quantum transport and magnetic phenomenon can interact, leading to measurements of an unprecedented precision. [1] Bogani L. and Wernsdorfer W. Nature Mat. 7, 179 - 186 (2008) [2] Moon-Ho Jo et al., Nano Letters 6 , 9 (2006) [3] Heersche H.B. et al, Phys. Rev. Lett. 96, 206801 (2006) [4] Vitali L et al., Nano letters, 3364-8 (2008) [5] Margheriti L. et al. Advanced materials, 1-6 (2010) [6] Ishikawa N. et al., Angewandte Chemie, 44 (2005)

Mesoscopic thermodynamic effects, persistent current, thermal transport, meso-optomechanics, entanglement entropy.

C. Blanc

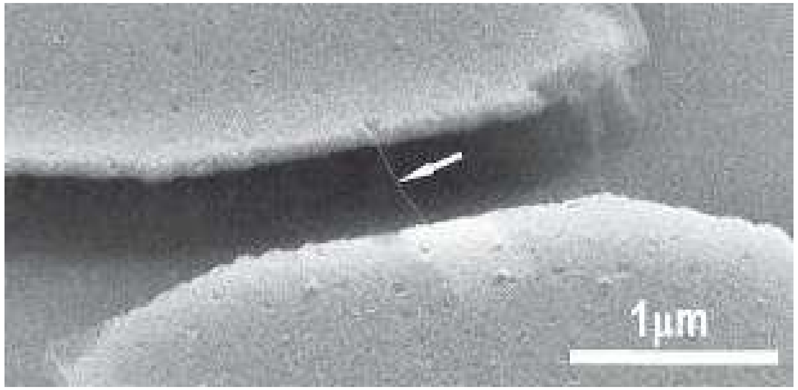
Quantum phonon transport in nanostructure at low temperature

In this poster, i will show the 3 omega method we use in the group to measure the thermal conductivity in silicon nanowire. I will explain the new method i am developing in order to reach 15 mK. In a second time i will show the results obtain by Jean-Savin Héron in nanowire with a serpentine. I will show the first results i obtain in nanowire with catenoidal contact, and the other system i want to measure (phononic crystal, phononic diode,...). Acknowledgment : - The 3 omega method : - D. G. Cahill, Rev. Sci. Instrum. 61, 802 (1990) - L. Lu, W. Yi et D. L. Zhang, Rev. Sci. Instrum. 72, 2996 (2001) - O. Bourgeois, Th. Fournier, and J. Chaussy, J. Appl. Phys. 101, 016104 (2007) - The experiments : - J-S. Heron, C. Bera, T. Fournier, N. Mingo, and O. Bourgeois, Blocking phonons via nanoscale geometrical design, PHYSICAL REVIEW B 82, 155458 (2010) - Yann Chalopin, Jean-Numa Gillet, and Sebastian Volz, Predominance of thermal contact resistance in a silicon nanowire on a planar substrate, PHYSICAL REVIEW B, 77, 233309 (2008) - A.N. Cleland, D.R. Schmidt, and C.S. Yung, Thermal conductance of nanostructured phononic crystals, PHYSICAL REVIEW B, 64,172301 (2001)

J. Chaste

Negative thermal expansion in carbon nanotube resonators

Electromechanical resonators based on carbon nanotube have attracted recently a lot of attention. Suspended carbon nanotube resonators combine very low mass (m), and very high spring constant (k) due to the high energy bonds between carbon atoms. This result in a remarkably high resonant frequency, f0=1/2p(k/m)0.5, as high as 1Ghz. Recent improvement in the fabrication allows us to obtain high purity samples with low dissipation (Q>7400 at 7K). Nanotube resonators are also very interesting as inertial mass sensors. Here, we report on measurements on nanotube under build-in tension. We show that the resonant frequency is extremely sensitive to a longitudinal elongation. The elongation sensibility of our device is measured to be 10 fm. We studied the thermal expansion over a broad temperature range, from 4K to 300K. We found that the nanotube contract when increasing temperature, in contrast to most other materials. In addition, the thermal dilatation coefficient, a=1/??T. ??L/L, is very large (a=-8.10-6 K-1) in agreement with theoretical work (1). This behavior is a result of the thermal excitation of long wavelength phonons that translate into a longitudinal contraction. These predictions were not experimentally tested. 1)Negative thermal expansion in carbon nanotube resonators J.Chaste, M. Zdrojek, J. Moser, A. eichler, A. Bachtold Y.-K. Kwon, S. Berber, D. Tom?nek, Phys. Rev. Lett., 92, 015901 (2004)



JL Pichard

Thermal Enhancement of Interference Effects in Quantum Point Contacts

We study an electron interferometer formed with a quantum point contact and a scanning probe tip in a two-dimensional electron gas. The images giving the conductance as a function of the tip position exhibit fringes spaced by half the Fermi wavelength. For a contact opened at the edges of a quantized conductance plateau, the fringes are enhanced as the temperature T increases and can persist beyond the thermal length l_T. This unusual effect is explained assuming a simplified model: The fringes are mainly given by a contribution which vanishes when T \to 0 and has a decay characterized by a T-independent scale. Ref: arXiv:1011.4559v1 [cond-mat.mes-hall] by Adel Abbout, Gabriel Lemarié and Jean-Louis Pichard