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Tunable oupling between two quantum dots through another central one

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We have previously realized a spin qubit in a silicon CMOS device based on two quantum dots. An important step toward the realisation of a quantum circuit is the coupling between nearest neighbors quantum dots. Here we report on coupling between two accumulations dots through another central dot. We show that the tunnel coupling between these two outers dots strongly depends on the density of states of the central one. Its occupation modifies the electrostatics and therefore the stability diagram.

Keywords: Quantum dots, Tunable coupling, Charge states, CMOS, Stability diagram, excited states

*Speaker

Inelastic Cooper Pair Tunneling: Multiplication of Propagating Microwave Photons.

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Cooper pair transport through a Josepshon junction is usually elastic: the DC voltage across the junction has to be zero to allow for tunneling through the junction. By coupling a DC voltage-biased junction to a microwave circuit, the light-charge interaction enables inelastic charge transport with photons emission or absorption. The strong nonlinearity of this interaction makes it possible to design sources of nonclassical microwave radiation, parametric amplifiers or in our case, a photon multiplier.

By designing particular high impedance electromagnetic environments, the multi-photon process can become dominant. In this case, we can show that the energy of a tunneling Cooper pair can be used to convert an incoming single photon state into a n-photon Fock state in a different mode. This multiplication process can be repeated to discriminate the single photon state from vacuum through linear post-amplification. I will present the theory of this photo-multiplication process as well as the design of a microwave circuit implementing it.

Keywords: Superconducting quantum circuits, Microwave single photon detectors, Josephson Photonics

*Speaker

Heat Coulomb blockade of one ballistic channel

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Quantum mechanics and Coulomb interaction rule heat and charge transport in small circuits, giving rise to many-body phenomena (Coulomb blockade, Luttinger liquids, Kondo effect...). Whereas many experiments address electrical properties, consequences on thermal transport remain mostly unexplored.
In this presentation, I will show that the Coulomb interaction influence on heat transport can be drastically different than on electrical transport, in violation of the Wiedemann Franz law (relating charge and thermal conductances). Using a hybrid metal-semiconductor circuit with N parallel ballistic channels connected to a floating node, we demonstrate the systematic blockade of exactly one thermal conductance quantum, whereas there is no such blockade on the electrical conductance [1].
E. Sivre *et al.*, to appear in Nat. Phys. (10.1038/nphys4280)

Keywords: heat transport, semiconductor heterostructures, Coulomb blockade, quantum conductors

*Speaker

Bistability and Displacement Fluctuations in a Quantum Nano-mechanical Oscillator

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Remarkable features have been predicted for the mechanical fluctuations at the bistability transition of a classical oscillator coupled capacitively to a quantum dot [Phys. Rev. Lett. **115**, 206802 (2015)]. These results have been obtained in the regime of temperatures larger than the mechanical resonating frequency but smaller than the electronic tunneling rate.
A similar behavior could be expected in the quantum regime, for which the temperature is smaller than the mechanical resonating frequency but larger than the electronic tunneling rate. We thus calculate the displacement fluctuation spectrum of the mechanical oscillator and study its behavior as a function of the electro-mechanical (or electron-phonon) coupling constant when the system enters the Frank-Condon regime. We find that, in analogy with the classical case, it shows a maximum width when the bistability establishes, but for quite different reasons.

Keywords: Nanoelectromechanical systems ; Quantum transport ; Quantum noise

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Non-uniform superconducting phases generated by spin-orbit interaction

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Non-uniform superconducting states raise great interest in the scientific community. One of the most famous is the FFLO state, predicted in the 1960's. It is characterized by a higher critical field than the uniform superconducting state. The FFLO state appears at low critical temperature, which makes it difficult to observe experimentally. In this presentation, we will show that adding spin-orbit interaction allows the modulated phase to appear at high critical temperature.The system studied consists of a superconducting nanowire with Zeeman field and Rashba spin-orbit interaction.

Keywords: Non uniform superconductivity, FFLO, spin orbit interaction

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An on-demand source of anti-bunched microwave photons

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Most superconducting devices use the Josephson junction in the zero-voltage branch where the junction behaves as a nonlinear inductor. However, Cooper pairs can tunnel through the Josephson junction also at non-zero bias voltage if the energy of a tunneling Cooper pair can be dissipated somehow, e.g. in the form of photons [1]. By coupling the junction to a transmission line, we can detect these photons associated to inelastic Cooper pair tunneling [2] and measure their statistics. In most configurations, the emitted photons have the same poissonian statistics as the tunneling Cooper pairs, corresponding to independent tunneling events. However, by designing particular high-impedance microwave circuits, we can tune the photon statistics to also be non-classical [3]. I will show that the photons emitted by such a circuit can be strongly anti-bunched. In addition, we have replaced the Josephson junction by a SQUID which allows us to modulate the effective Josephson energy by applying magnetic flux pulses. We use these pulses to generate anti-bunched photons on demand up to rates $>$ 100 MHz.

T. Holst et al., Phys. Rev. Lett. 73, 3455 (1994)

M. Hofheinz et al., Phys. Rev. Lett. 106, 217005 (2011)

J. Lepṕakangas et al., Phys. Rev. Lett. 115, 027004 (2015)

Keywords: Josephson photonics, Single photon source, Microwave photon

*Speaker

Superconducting Silicon Resonators

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We have studied superconducting resonators made of boron doped silicon. The superconductivity of silicon appears for very high doping concentrations, with a critical temperature increasing from 0.6 at.% to 10 at.% of boron in the lattice. To achieve such high doping levels, we employ laser doping, an out-of-equilibrium technique that allows one to exceed the solubility limit of boron in silicon. Si:B is a BCS superconductor, with a maximum critical temperature of 0.7 K. We have structured Si:B into coplanar waveguide resonators, and measured the behaviour of the resonance frequency and quality factor with temperature, power and resonator width. We show in particular that the temperature dependence of the resonances is well fitted with the Mattis-Bardeen theory. Quality factor with temperature and resonator width are still to be understood. Due to its high resistivity (around 100 μOhm.cm) and low critical temperature, Si:B has a high kinetic inductance (around 40 pH per square), making this material potentially interesting for Kinetic Inductance Detectors.

Keywords: Superconducting Resonators, Gas Immersion Laser Doping, Kinetic Inductance, Mattis Bardeen theory, KIDs

*Speaker

Tunneling spectroscopy of graphene nanodevices proximitized by superconductors

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A normal conductor placed in good contact with a superconductor can inherit its electronic properties. This proximity effect originates from the formation in the conductor of electron-hole states, called Andreev bound states (ABS). Spectroscopic studies of ABS have been performed in just a handful of systems. The unique geometry, electronic structure and high mobility of graphene make it a novel platform for studying Andreev physics in two dimensions. Here we use a full van der Waals heterostructure to perform tunneling spectroscopy measurements of proximitized graphene, using either aluminum or niobium-nitride as superconductors. The measured energy spectra, which depend on the phase difference between the superconductors, reveal a continuum of ABS. Moreover, we measure the Andreev spectrum as a function of the graphene Fermi energy, showing the influence of scattering in graphene. From the phase dependence of the spectra, we further infer the supercurrent carried by the ABS, thus relating Andreev physics and the Josephson effect. At last, we discuss the origin of phase-dependent features that occur at energies larger than the superconducting gap.

Keywords: Graphene, Andreev bound states, Tunneling spectroscopy, Josephson Effect, Quantum dots

*Speaker

Observing a Quantum Maxwell Demon at Work

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In apparent contradiction to the laws of thermodynamics, Maxwell's demon is able to cyclically extract work from a system in contact with a thermal bath exploiting the information about its microstate. The resolution of this paradox required the insight that an intimate relationship exists between information and thermodynamics. Recent experiments have realized classical versions of elementary Maxwell demons in various physical systems. While quantum versions have long been investigated theoretically, experimental realizations are in their infancy and a full characterization is still missing. Here, we present the realization of a Maxwell demon experiment that tracks the state of each constituent both in the classical and quantum regimes. The demon is a microwave cavity that encodes quantum information about a superconducting qubit and converts information into work by powering up a propagating microwave pulse by stimulated emission. Importantly, we are able to directly probe the extracted work by measuring the output power emitted by the system through stimulated emission, without inferring it from system trajectories. We are thus able to demonstrate how the information stored in the demon's memory affects the extracted work. To make the characterization complete, we also measure the entropy and energy of the system and the demon. Superconducting circuits thus reveal themselves as a suitable experimental testbed for the blooming field of quantum thermodynamics of information.

This work has been published in the Proceedings of the National Academy of Sciences 114 (29), 7561-7564 (2017)

Keywords: Quantum thermodynamics, Superconducting circuits

*Speaker

Embracing CMOS and quantum technology in Silicon

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The spin carried by a single electron is a prototypical quantum bit, or qubit.
The possibility of embedding isolated, spin charges in commercial transistors opens the way to a potential scale-up of technology for quantum information processing. Such approach presents a promising combination of environmental isolation and controllability, with mature semiconductor industry. This double-face benefit is glaring for Silicon, the dominant material used for conventional microprocessor chips.

Research on Si-based spin qubits has seen a tremendous progress over the past five years. Our approach consists in obtaining complementary metal–oxide–semiconductor (CMOS) transistors with qubit functionality by operating p-type devices at mK temperatures. Holes are trapped in quantum dots, can be handled by DC electric fields and their spin can be manipulated by AC electric field thanks to spin-orbit coupling.
We demonstrated full, two-axes control of the first qubit realized by industrial CMOS technology and, more recently, have scratched the top of the complex spin-orbit physics in the play. Current efforts are dedicated to the development of fast single-spin readout by radio-frequency gate reflectometry, in parallel with device optimization to scalable spin qubit geometries. Holes spins are emerging as unexpected, but finally welcome, contender in the marathon towards future quantum processors.

Keywords: Silicon, CMOS, spin, qubit, spin, orbit

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STAMPING CARBON NANOTUBES FOR CIRCUIT QUANTUM ELECTRODYNAMICS

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Dry transfer technique of CVD-grown carbon nanotubes is an important step to embed them in high quality devices. This is for example instrumental towards the fabrication of quantum electrodynamics circuits such as double quantum dots (DQD) in order to achieve the strong spin-photon coupling [1]. We need to combine high finesse microwave cavities with high quality carbon nanotube. The fabrication of such structures is a priori an experimental challenge since the superconducting microwave cavities made of metals such as Al or Nb are not compatible with the growth conditions of carbon nanotubes.

Here we present improvements in our current stamping technique [2, 3], for which the carbon nanotubes have to be exposed to an electron lithography step. This is detrimental for the nanotube quality as found from Raman spectroscopy, where defect associated signal (the D band) was observed. We have developed a stamping technique based on cantilevers where the tubes are directly deposited on the contacts [4]. This allows us to obtain higher tube quality, an increased tube transfer yield with better tube selection, suspended nanotubes, and the possibility to reuse our lithographed devices.

This method can be easily extended to transfer tube in other devices where selection of a single tube is important.

References

J. J. Viennot, M. C. Dartiailh, A. Cottet, T. Kontos, Science 349, 408 (2015).

J. J. Viennot, J. Palomo, T. Kontos, Appl. Phys. Lett. 104, 113108 (2014).

M. M. Desjardins, J. J. Viennot, M. C. Dartiailh, L. E. Bruhat, M. R. Delbecq, M. Lee, M.-S. Choi, A. Cottet, T. Kontos, Nature 545, 71 (2017).

J. Waissman et al. Nature Nanotech. 8, 569 (2013).

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Keywords: CNT, superconducting microwave cavities, hybrid quantum circuits, double quantum dots

Dynamical compressibility of the quantum spin Hall insulator HgTe

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Quantum spin Hall (QSH) insulators are two-dimensional electron systems which host spin-polarized edge states while the bulk remains insulating. These helical edge states provide a potential support system to encode information in 'topological quantum bits' robust to the decoherence. Despite immense theoretical and experimental efforts, the rise of these new materials has however been hampered by strong difficulties to clearly observe their predicted topological properties. These challenges motivate the investigation of the dynamics of their topological edge states using microwave techniques. Here we report on the compressibility of the QSH insulator HgTe, measured in the GHz range in metal-oxyde-HgTe capacitors. It simultaneously yields both the quantum capacitance and the resistance of the device, which reflect the expected band structure of the HgTe quantum wells. In particular, a capacitance minimum associated to a resistance maximum signal the QSH regime but also indicate the presence of a residual two-dimensional contribution to the electronic transport. We analyze the role of inhomogeneous gating and disorder, and investigate ways to optimize the QSH transport properties.

Keywords: HgTe, topological insulators, microwave, compressibility

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Réalisation du modèle de Haldane avec des fermions ultra-froids

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Une structure de bande topologiquement non triviale apparaît dans un réseau hexagonal si la symétrie de renversement du temps est brisée, comme suggéré par F. D. M. Haldane. Il a en outre souligné que, en combinaison avec une brisure de symétrie spatiale, cela donne lieu à un diagramme de phases contenant des phases topologiquement distinctes, mais sans la nécessité d'un champ magnétique. En étudiant une structure de bande d'un réseau hexagonal avec une symétrie d'inversion de temps brisée par des couplages seconds-voisins complexes, il a montré que les frontières des phases topologiquement distinctes correspondent à la fermeture d'un gap aux points de Dirac. Bien qu'il soit difficile de réaliser ce modèle dans un matériau, il a néanmoins fourni une base conceptuelle pour d'autres isolants topologiques, ainsi que pour l'effet Hall de spin quantique. Les perspectives de réaliser ce modèle avec des atomes froids découlent des progrès effectués dans la création de champs magnétiques effectifs pour des atomes neutres. En particulier, l'utilisation de potentiels dépendant du temps permet de briser la symétrie de renversement du temps dans un réseau hexagonal. Je présenterai la réalisation du modèle de Haldane dans un réseau optique hexagonal dépendant du temps. En déplaçant le réseau optique selon une trajectoire circulaire, un couplage complexe entre seconds-voisins apparaît, et un gap s'ouvre dans la structure de bande. Ce gap est mesuré en induisant des transitions inter-bandes résolues en impulsion. Par analogie avec une conductance de Hall, nous observons également un déplacement caractéristique du nuage atomique lorsqu'une force constante est appliquée. De plus, la flexibilité offerte par les systèmes d'atomes froids permet d'envisager la création d'une interface entre une phase topologique et une phase triviale. Cette interface contient nécessairement un état de bord, dont la vitesse de groupe et la chiralité peuvent être détectés par des méthodes d'imagerie conventionnelles, ce qui est confirmé par une étude numérique.

Keywords: Haldane, fermions ultrafroids, Floquet

*Speaker

Geometrical phase shift in Friedel oscillations

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This work revisit the natural problem of elastic scattering through a localized impurity in a one-dimensional
crystal in the presence of sublattice freedom degrees. The impurity yields long-range interferences in the local density of

states known as Friedel oscillations. Here, we show that the internal degrees of freedom of Bloch waves are

responsible for a geometrical phase shift in Friedel oscillations. The Fourier transform of the energy-resolved

interference pattern reveals a topological property of this phase shift, which is intrinsically related to the Bloch
band structure topology (quantized Zak/Berry phase) without impurity. Therefore, Friedel oscillations in the local density of states can be regarded as a probe of wave topological properties in a broad class of classical and quantum systems, such as acoustic and photonic crystals, ultracold atomic gases in optical lattices, and electronic compounds.

Keywords: Elastic scattering, Friedel interferences, Berry phase, Scanning tunnelling microscopy, Artificial crystals

*Speaker

Thermal Conductance of a Single Electron Transistor

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Heat flow at mesoscopic scale is a fundamentally important issue, in particular, if it can be converted in to energy by thermoelectric effect. While the understanding of charge transport in mesoscopic system has reached a great level of maturity, heat transport lagging far behind. According to the celebrated Wiedemann-Franz law, the charge conductance is proportional to the thermal conductance. In nanoscale devices, this law is predicted to be violated when the electron-electron interaction is strong [1].
We have carried out a combined measurement of heat and charge transport through a single-electron transistor (SET). A thermal gradient across the SET is created by cooling (heating) the source using a (pair of) NIS junction while the source temperature was simultaneously measured (*FIG. 1*, top-left). A periodic modulation of the source temperature (*FIG. 1*, bottom-left) as a function of gate voltage is observed, having a sign depending on the direction of heat flow. The device thus acts as a heat switch actuated by the voltage applied on the gate. The Lorentz ratio $L/L0$ ($L0$ being the Lorentz number) is calculated by comparing the charge and heat transport data (*FIG. 1*, bottom-right). While the Wiedemann-Franz law predicts a unity value for the Lorentz ratio, a value up to 4.5 is observed [2]. This observations agrees well with theoretical calculations.

References:

B. Kubala, J. Knig, J. P. Pekola, Violation of Wiedemann-Franz Law in a Single-Electron Transistor, Phys. Rev. Lett. **100**, 066801 (2008)

B. Dutta, J. T. Peltonen, D. S. Antonenko, M. Meschke, M. A. Skvortsov, B. Kubala, J. Knig, C. B. Winkelmann, H. Courtois, J. P. Pekola, Thermal Conductance of a Single-Electron Transistor, Phys. Rev. Lett. **119**, 077701 (2017)

Keywords: Single Electron Transistor, Thermal Conductance, Heat transport at nanoscale, Wiedemann Franz law

*Speaker

Wave function correlations and the AC conductivity of disordered wires beyond the Mott-Berezinskii law

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The Mott-Berezinskii law is one of the most important results on the wave function correlations in disordered systems. Even in 1D case which is amenable to powerful non-perturbative methods, the knowledge about the wave function correlations is still limited. The 1D methods such as the phase formalism, provide access to spectral and localization properties which are much more difficult to obtain in higher dimensions but they are useless for the wave function correlations at different energies, dynamical response functions, and the finite-frequency (AC) conductivity. According to the Mott's intuitive arguments, correlations of wave functions at close energies may be described in terms of hybridization of localized states [1]. The leading mechanism for the AC conductivity is then the resonant tunneling between pairs of localized states. Using that the states in 1D are localized at any energy even by a weak disorder Berezinskii later on invented a diagrammatic technique special for 1D which allows one to derive the Mott formula in the limit of large positive energies [2] .

The Mott's intuitive arguments can be put on a rigorous basis by applying the instanton approach to the statistics of wave functions and AC transport valid in the tails of the spectrum, i.e. for large negative energies. We have recently developed a method of computing functional determinants which allows one to perform these instanton calculations exactly [3]. Using our method we derived correlators of wave functions at different energies and calculate the AC conductivity beyond the leading order in small frequency given by the Mott-Berezinskii law [4]. These results show the difference in statistical properties of states localized at large negative and large positive energies. The method can be also applied to the AC transport in quasi one-dimensional systems.

N.F. Mott, Philos. Mag. **17**, 1259 (1968).

V.L. Berezinskii, Sov. Phys. JETP **38**, 620 (1974).

G.M. Falco, A.A. Fedorenko, and I.A. Gruzberg, arXiv:1703.07329 (2017).

G.M. Falco, A.A. Fedorenko, and I.A. Gruzberg, arXiv:1708.07163 (2017).

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Keywords: disordered wires, AC conductivity, Mott, Berezinskii

A chiral Josephson transistor

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Irradiating a Josephson junction with microwaves can operate not only on the amplitude but also on the phase of the Josephson current. This requires breaking time inversion symmetry, which is achieved by introducing a phase lapse between the microwave components acting on the two sides of the junction. General symmetry arguments and the solution of a specific single level quantum dot model show that this induces chirality in the Cooper pair dynamics. Another essential condition is to break electron-hole symmetry. A shift of the current-phase relation is obtained, controllable in sign and amplitude with the microwave phase and an electrostatic gate, producing a chiral Josephson transistor. The dot model is solved in the infinite gap limit by Floquet theory and in the general case with Keldysh nonequilibrium Green's functions. The chiral current is nonadiabatic and changes sign close to resonant chiral transitions between the Andreev bound states [1]. [1] B. Venitucci et al., arXiv:1708.03262

Keywords: Josphson effect, microwave irradiation, quantum pumps

*Speaker

Collective plasmons in metasurfaces of near-field coupled metallic nanoparticles

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Since a few years, plasmonic nanostructures have witnessed a boost of interest due to their ability
to perform subwavelength optics. Indeed, plasmonic metamaterials present appealing features, such
as the possibility to trap and control light at the nanoscale. Periodic arrays of metallic nanoparticles
are of particular interest since they support collective plasmonic modes which are extended over the
whole metasurface. Such collective modes arise due to the dipolar interaction between localized surface
plasmons on each nanoparticle, opening a new way to transport light at the nanoscale.
A crucial quantity to evaluate for future applications is the lifetime of the collective modes. For a single nanoparticle, the plasmon suffers from both radiative and nonradiative damping processes
which strongly depend on the nanoparticle size. However, in 2D arrays, the interactions between the
nanoparticles significantly modifiy the decay rates.
We present a theoretical framework to obtain the full quasi-static plasmonic bandstructure and evaluate the different decay mechanisms for generic 2D periodic arrays of metallic nanoparticles. We
apply our results to arrays with various geometries. Among them, we concentrate on the cases of the
honeycomb, Lieb and Kagomé lattices. In particular, we study the influence of the long-range nature
of the dipolar interactions on these lattices which may present interesting topological features such as
Dirac-like plasmons [1,2] and nondispersive plasmonic bands.

G. Weick, C. Woollacott, W. L. Barnes, O. Hess, and E. Mariani, PRL 110, 106801 (2013)
T. J. Sturges, C. Woollacott, G. Weick, and E. Mariani, 2D Materials 2, 014008 (2015)

Keywords: plasmons, lifetime, honeycomb, Lieb, Kagomé

*Speaker

High-power collective charging of a solid-state quantum battery

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Quantum information theorems state that it is possible to exploit collective quantum resources to
greatly enhance the charging power of quantum batteries (QBs) made of many identical elementary

units. We here present and solve a model of a QB that can be engineered in solid-state architectures.

It consists of N two-level systems coupled to a single photonic mode in a cavity. We contrast this

collective model ("Dicke QB"), whereby entanglement is genuinely created by the common photonic

mode, to the one in which each two-level system is coupled to its own separate cavity mode ("Rabi

QB"). By employing exact diagonalization, we demonstrate the emergence of a considerable quantum

advantage in the charging power of Dicke QBs.

Keywords: Quantum battery, charging power, quantum enanchement

*Speaker

Qubit dynamics while simultaneously monitoring relaxation and dephasing

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Measuring a spin-1/2 along one direction projectively maximally randomizes the outcome of a following measurement along a perpendicular direction. Here, going beyond projective measurements alone, we explore the dynamics of a superconducting qubit for which we measure simultaneously the three components x, y and z of the Bloch vector.
The x and y components are obtained by measuring the two quadratures of the fluorescence field emitted by the qubit. Conversely the z component is accessed by probing an off-resonant cavity dispersively coupled to the qubit. The frequency of the cavity depends on the energy of the qubit and the strength of this last measurement can be tuned from weak to strong in situ by varying the power of the probe.

In this experiment, the tracked system state diffuses inside the Bloch sphere and performs a random walk whose steps obey specific rules revealing the backaction of incompatible quantum measurements. The associated quantum trajectories follow a variety of dynamics ranging from diffusion to Zeno blockade. Their peculiar dynamics highlight the non trivial interplay between the backaction of the two aforementioned incompatible measurements.

Keywords: superconducting circuit, qubit, incompatible measurement, quantum noise, quantum measurement, quantum back action

*Speaker
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Frequency-conversion of a qubit ultra-strongly coupled to a waveguide

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Non-linear quantum optics usually relies on the strong pumping of an emitter, owing to the smallness of the fine structure constant. Superconducting metamaterials such as Josephson junction waveguides display in contrast an enhanced light-matter interaction up to values of order one. This so-called ultra-strong coupling regime of waveguide-QED allows the generation of non-linear effects associated to non-classical multi-photon emission for a two-level artificial atom, even at vanishingly small incident power. Using a controlled numerical many-body scattering method based on multi-modes Schr'odinger cats, and a comparison with RWA input-output theory, we surprisingly find that non-resonant emission associated to frequency conversion is dominated by non-rotating-wave contributions, due to a large phase space for particle production. This detailed study of inelastic emission spectra should be useful to guide experiments aiming at probing non-linear emission processes in waveguide quantum electrodynamics.

Keywords: Non linear quantum optics, Josephson waveguides, many body effects, numerical simulations

*Speaker

Observing The Topological Invariant of Bloch Bands Using Quantum Walks in Superconducting Circuits

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The direct measurement of topological invariants in both engineered and naturally occurring quantum materials is a key step in classifying quantum phases of matter. Here we motivate a toolbox based on time-dependent quantum walks as a method to digitally simulate single-particle topological band structures. Using a superconducting qubit dispersively coupled to a microwave cavity, we implement two classes of split-step quantum walks and directly measure the topological invariant (winding number) associated with each. The measurement relies upon interference between two components of a cavity Schrodinger cat state and highlights a novel refocusing technique which allows for the direct implementation of a digital version of Bloch oscillations. Our scheme can readily be extended to higher dimensions, whereby quantum walk-based simulations can probe topological phases ranging from the quantum spin Hall effect to the Hopf insulator.

Keywords: Quantum Simulation

*Speaker

Quantum Thermalization and Spontaneous Symmetry Breaking

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Recent progress in the field of quantum simulation has greatly expanded our understanding of the time evolution of out-of-equilibrium quantum systems prepared in isolation. A central question in the subject of isolated quantum dynamics is whether an isolated quantum system, initially prepared in a pure, out of equilibrium quantum state, will come to a state of thermal equilibrium under its own internal quantum dynamics, and if so, what is the mechanism by which this process occurs. Recent experiments have shown that quite generically, isolated quantum systems can and do come to a state of local thermal equilibrium, in which measurements made on subsystems are indistinguishable from those made on a system described by a thermal density matrix. The "Eigenstate Thermalization Hypothesis" has been put forward as the mechanism for such a phenomenon when the global time evolution is unitary, thus preventing true thermalization of the global quantum state. The remarkable prediction of the Eigenstate Thermalizaton Hypothesis, which has been verified in a wide variety of theoretical investigations, is that in a non-integrable quantum system, individual energy eigenstates encode a significant amount of information about the thermal behaviour of the system. In this seminar, I will discuss the history of the subject of isolated quantum thermalization in broad detail, along with the recent work I and my colleaugues have conducted, dedicated to the (numerical) investigation of whether eigenstate thermalization is compatible with another paradigm of statistical mechanics, spontaneous symmetry breaking.

Keywords: quantum dynamics, quantum thermalization, statistical mechanics, quantum chaos, symmetry breaking

*Speaker

Hofstadter butterfly of a quasicrystal

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The energy spectrum of a tight-binding Hamiltonian is studied for the two-dimensional quasiperiodic Rauzy tiling in a perpendicular magnetic field. This spectrum known as a Hofstadter butterfly displays a very rich pattern of bulk gaps that are labeled by four integers, instead of two for periodic systems. The role of phason-flip disorder is also investigated in order to extract genuinely quasiperiodic properties. This geometric disorder is found to only preserve main quantum Hall gaps.

Keywords: Hofstadter butterfly, quasi, crystals, Chern insulators, quantum Hall effect

*Speaker

Simulating artifcial graphene in circuit-QED

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We present an experimental study of the eigenmodes and the dispersion relation of an artificial honeycomb lattice made of superconducting resonators. We image the spatial distribution of the modes using a low temperature laser scanning microscopy based on the variation of the microwave transmission of the lattice. This variation is induced by the absorbed laser power by a site of the lattice and is proportional to the weight of the probed mode on this site. In addition to mode labeling, mode imaging enables the reconstruction of the dispersion relation by Fourier transform. We were also able to investigate edges-states modes. In order to model the lattice, we have developed an ab initio method to calculate its spectrum by simulating a few resonators on electromagnetic software. This modelization provides an effective tight-binding Hamiltonian that is in good agreement with experimental data.

Keywords: Quantum simulator

*Speaker

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CryoHEMTs made at C2N for low-temperature readout electronics: performance and mesoscopic applications

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A long-term investigation has been conducted at C2N/LPN, in order to fill the gap of high performance field-effect transistors) for high impedance, low-power and low-frequency deep cryogenic readout electronics, and to meet the needs of various experiments from astrophysics to mesoscopic physics. We are now capable to fabricate ultra-low noise cryoHEMTs (cryogenic High Electron Mobility Transistors) working at low frequencies and low temperature from 77 K down to 4.2K, or even lower. We can offer specific cryoHEMTs according to the needs of various experiments.
Specifically, the cryoHEMTs have been an essential for a number of high-impact mesoscopic physics investigations, e.g., the quantum limit of heat flow across a single electronic channel [*Science* 342, 601 (2013)], Hong-Ou-Mandel experiment for temporal investigation of single-electron fractionalization [*Nature Commun.* 6, 7854 (2015)], Primary thermometry triad at 6mK in mesoscopic circuits [*Nature Commun.* 7, 12908 (2016)]. The typical performance of the devices in these investigations have been, for an input capacitance of about 3.5 pF and a power consumption of 100 μW at 4.2 K: an equivalent input noise voltage and a noise current at 4.2 K of 1.4 nV/$\sqrt{}$Hz and 70 aA/$\sqrt{}$Hz @ 1 kHz, respectively; and a white noise voltage of about 0.2 nV/$\sqrt{}$Hz.

Other mesoscopic experiments using cryoHEMTs:

Low-temperature STM by Marco Aprili and Freek Massee at LPS, Orsay.

Low-temperature nano mechanical resonators by Adrian Bachtold at ICFO, Barcelona.
In addition, our cryoHEMTs are also used by Stahl Electronics (a German company) for realizing cryogenic readout electronics for various scientific instruments.

Keywords: Cryo HEMT

*Speaker

Operating Quantum States in Single Magnetic Molecules: Implementation of Quantum Gates and Algorithm

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The application of quantum physics to the information theory turns out to be full of promises. The first step is to realize the basic block that encodes the quantum information, the qubit. Among all existing qubits, spin based devices are very attractive since they reveal electrical read-out and coherent manipulation. Beyond this, the more isolated a system is, the longer its quantum behavior remains, making of the nuclear spin a serious candidate for exhibiting long coherence time and consequently high numbers of quantum operation.

In this context I worked on a molecular magnet spin transistor. This setup enabled us to read-out electrically both the electronic and the nuclear spin states and to coherently manipulate the nuclear spin of the Terbium ion [1,2]. I will present the study of the dynamic of a single 3/2 nuclear spin under the influence of a microwave pulse. After the energies difference measurement between these states I will show the coherent manipulation of the three nuclear spin transitions up to 10MHz using only a microwave electric field with coherence time higher than 1ms.

More than demonstrating the qubit dynamic, these measures demonstrate that a nuclear spin embedded in a molecular magnet transistor is a four quantum states system that can be fully controlled. Theoretical proposal demonstrated that quantum information processing could be implemented using a 3/2 spin such as quantum gates [3] and algorithm [4]. I will present the implementation of the Grover algorithm [5] to then show the implementation of the iSWAP gate and the measurement of its phase.

Thiele S. et al. Science 344, 1135 (2014)

Godfrin C. et al. ACS Nano 11, 3984 (2017)

Kiktenko E. O. et al. Phys. Rev. A 91, 042312 (2015)

*Speaker

Leuenberger M. et al. Phys. Rev. Lett. 89, 207601 (2003)

Godfrin C. et al. accepted to Phys. Rev. Lett. (2017)

Keywords: Molecular magnet, single nuclear spin, Coherent manipulation, Quantum algorithm

Surface states in smooth topological heterojunctions

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Motivated by the experimental findings from the Mesoscopic-Physics group at LPA-ENS [1], we study theoretically smooth topological interfaces, i.e. interfaces between a topological and a normal insulator. In addition to the usual topologically protected chiral surface states, which do not depend on the specific form of the interface, several massive states appear if the interface width is larger than a particular intrinsic length (given by the bulk gap and the Fermi velocity). These states, first described by Volkov and Pankratov (VP) in the 1990ies [2], are intrinsically relativistic and can be related to Landau bands of relativistic fermions. We show that the gap variation can be interpreted precisely as a vector potential that is affected by an additional electric field in a relativistic manner [3]. The electric field can thus be used not only to dope electronically these massive surface states, but they become even more accessible due to the reduction of the Landau gap in the presence of an electric field. The effect is at the origin of an oscillating resistance measured as a function of the electric field in high-frequency experiments at LPA-ENS [1]. [1] "Observation of Volkov-Pankratov states in topological HgTe heterojunctions
using high-frequency compressibility", A. Inhofer, S. Tchoumakov, B.A. Assaf, G. Fève, J.M. Berroir, V. Jouffrey, D. Carpentier, M. O. Goerbig, B. Plaçais, K. Bendias, D.M. Mahler, E. Bocquillon, R. Schlereth, C. Br´une, H. Buhmann, and L.W. Molenkamp, Phys. Rev. B (in press).

"Two-dimensional relativistic electrons in an inverted contact", JETP Lett. 42, 178 (1985).

"Volkov-Pankratov states in topological heterojunctions", S. Tchoumakov, V. Jouffrey, A. Inhofer, E. Bocquillon, B. Plaçais, D. Carpentier, and M. O. Goerbig, Phys. Rev. B (in press).

Keywords: topological insulators, HgTe, bulk, edge correspondence

*Speaker

Josephson Junction Spectroscopy of Mesoscopic Systems

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Josephson junctions are a unique system in which a DC excitation can produce microwave photons of energy directly proportional to the DC voltage. A Josephson junction can therefore be used as a spectrometer to probe matter and in particular the energy levels of mesoscopic systems.
The operation of such a spectrometer is based on the AC Josephson effect stating that a Josephson junction biased by a DC voltage V induces the coherent tunneling of Cooper pairs across the junction and the emission of photons of energy hf = 2eV for a voltage below twice the gap of the superconductor forming the junction. Spectroscopy can be achieved up to 174 GHz in the case of aluminum. This device has already been used to measure the spectrum of Andreev bound states.

The goal of this project is to improve the operation of this spectrometer by using a Superconducting QUantum Interference Device (instead of a single Josephson junction) which allows for a better coupling to the system of interest. Further improvements are a higher sensitivity, a lower background signal and a larger bandwidth.
Now that the spectrometer has been improved, it will be used to investigate systems such as multi-terminal junctions. These devices are very remarkable in the sense that the topological properties of their superconducting phases play an important role and allow for zero energy excitations which can be probed by the Josephson junction spectrometer.

Keywords: Supraconductivité mésoscopique, topologie, effet Josephson

*Speaker

Quantization and enhancement of non-linear responses in topological matter

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In this talk I will discuss three examples of nonlinear responses of topological matter, which can be quantized and/or remarkably large. The first and simplest is a quantized circular dichroism in Chern insulators: it can be probed by heating and it is related to an absorbed power sum rule. It does not rely on translational invariance, and its therefore applicable to fractional quantum Hall states. The second concerns the circular photogalvanic effect, the part of the photocurrent which changes sign when the light's polarization flips. In Weyl semimetals it is quantized in units of eˆ3/hˆ2 times the Weyl monopole charge, with no material-dependent parameters. It is predicted to be obsevable in mirror free Weyl semimetals (e.g. SrSi2) and three-dimensional Rashba materials (e.g. doped Te) and its magnitude is relatively large, which enables the direct detection of the monopole charge with current techniques. Lastly, I will discuss the recently observed giant and anisotropic second harmonic generation found in TaAs. In particular I will provide evidence that a class of ferroelectric materials have an upper bound for non-linear effects, and that TaAs is close to saturating it for a particular frequency range.

Keywords: Weyl semimetals, non linear optics, second harmonic generation, topological insulators

*Speaker

Kerr non-linearity in a superconducting Josephson metamaterial

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We present a detailed experimental and theoretical analysis of the dispersion and Kerr frequency shifts of plasma modes in a one-dimensional Josephson junction chain containing 500 SQUIDs in the regime of weak nonlinearity. The measured low-power dispersion curve agrees perfectly with the theoretical model if we take into account the Kerr renormalisation of the bare frequencies and long-range Coulomb interaction between island charges due to a remote ground plane. We measured the self- and cross-Kerr shifts for the frequencies of the eight lowest modes in the chain. We compare the measured Kerr coefficients with theory and find fairly good agreement.

Keywords: Josephson junction chain, Kerr effect, Dispersion of propagating plasmons, Superconducting Metamaterial

*Speaker

Orbital Magnetism in Gold Nanoparticles

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Despite extensive experimental research in the last 15 years, the puzzle of the origin of the unusual magnetic properties exhibited by assemblies of gold nanoparticles persists. While bulk gold is diamagnetic, nanoscopic gold samples may exhibit a ferromagnetic, paramagnetic or strongly diamagnetic response. To address the diversity in the experimental outcomes, we investigate the orbital motion of the valence electrons as a source of magnetism. By applying a semiclassical formalism, we calculate the magnetic susceptibility for a metallic nanoparticle in terms of electronic orbits. The theoretical calculation shows that for a single nanoparticle, the magnetic response highly oscillates with changing diameter between large diamagnetic and paramagnetic values. Moreover, when we analyze an ensemble of non-interacting nanoparticles, we find a purely paramagnetic susceptibility. Our analytical and numerical predictions describe a Curie-type law for low temperatures in samples that are well dispersed in the individual sizes. Our results are in excellent agreement with a fully quantum-mechanical approach.

Keywords: orbital magnetism, gold nanoparticles, semiclassical physics

*Speaker

Yu-Shiba-Rusinov impurities – building blocks of topological superconductors

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Magnetic impurities in a superconductor induce a pair-braking potential for Cooper pairs, which locally affects the Bogoliubov quasiparticles and gives rise to Yu-Shiba-Rusinov bound states [1]. The magnetic coupling strength of the impurity with the superconductor determines the bound state energy and the many-body ground state properties of the total system. Recently, Shiba physics saw a dramatic increase in interest triggered by the prediction of topological superconductivity and Majorana modes in magnetically coupled chains and arrays of Shiba impurities on s-wave superconductors.

Here, I present some of the physical insights into single magnetic adsorbates on s-wave superconductors we obtained by scanning tunneling microscopy. I will discuss tunneling processes into Shiba states [2], the influence of the orbital character of the impurity [3,4], and, finally, the coupling of impurities into dimers and chains and their relation to Majorana physics [5,6].

B. W. Heinrich, J. I. Pascual, K. J. Franke, arXiv:1705.03672 (review)

M. Ruby, F. Pientka, Y. Peng, F. von Oppen, B. W. Heinrich, K. J. Franke, Phys. Rev. Lett. 115, 087001 (2015).

M. Ruby, Y. Peng, F. von Oppen, B. W. Heinrich, K. J. Franke, Phys. Rev. Lett. 117, 186801 (2015).

D.-J. Choi, C. Rubio-Verdu, J. de Bruijckere, M. M. Ugeda, N. Lorente, J. I. Pascual, Nat. Comm. 15175 (2017).

M. Ruby, F. Pientka, Y. Peng, F. von Oppen, B. W. Heinrich, K. J. Franke, Phys. Rev. Lett. 115, 197204 (2015).

M. Ruby, B. W. Heinrich, Y. Peng, F. von Oppen, K. J. Franke, Nano Lett. 17, 4473 (2017).

Keywords: STM, scanning probe, Yu, Shiba, Rusinov, Majorana, topological superconductivity

*Speaker

On the road to the superconducting quantum computer?

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In this talk, I will present an overview of the current status of research towards quantum computing with superconducting circuits. We will cover various kinds of qubits, error correction schemes and the path to scaling up. We will also discuss who are the main actors at play and what are the pros and cons of superconducting circuits.

Keywords: quantum computer, superconducting circuits

*Speaker

Enhancement of the upper critical field in disordered transition metal dichalcogenide monolayers

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We study novel 2D materils ? transition metal dichalcogenide monolayers, which have a structure similar to graphene, but with two inequivalent sites in the unit cell. They exhibit a particularly strong intrinsic spin-orbit coupling (SOC), acting as an effective out-of-plane Zeeman field which takes opposite orientations in two different valleys. Intrinsic superconductivity has been experimentally realized in several of these compounds, with an in-plane upper critical field that greatly surpasses the Pauli limit ? a consequence of the 2D nature of these materials and the SOC [1,2,3]. We calculate the upper critical field in these superconductors for an arbitrary disorder strength. Our result captures the enhancement of the Pauli limit, and furthermore, diverges at zero temperature in the absence of intervalley scattering due to the SOC. It remains unaffected by the intravalley scattering, while the intervalley scattering suppresses the divergence [4]. We argue that moderate intervalley scattering could explain the experimental data. [1] Y. Saito et al., Nat. Phys. 12, 144 (2016) [2] J. Lu et al., Science 350, 1353 (2015) [3] X. Xi et al., Nat. Phys 12, 139 (2016) [4] S. Ilic et al., PRL 119, 117001 (2017)

Keywords: 2D materials, superconductivity

*Speaker

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Observation of Volkov-Pankratov states in topological HgTe heterojunctions using high-frequency compressibility

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It is well established that topological insulators sustain Dirac fermion surface states as a consequence of band inversion in the bulk. These states have a helical spin polarization and a linear dispersion with large Fermi velocity. In this article we report on a set of experimental observations supporting the existence of additional massive surface states. These states are also confined by the band inversion at a topological-trivial semiconductor heterojunction. While first introduced by Volkov and Pankratov (VP) before the understanding of the topological nature of such a junction, they were not experimentally identified. Here we identify their signatures on transport properties at high electric field. By monitoring the AC admittance of HgTe topological insulator field-effect capacitors, we access the compressibility and conductivity of surface states in a broad range of energies and electric fields. The Dirac states are characterized by a compressibility minimum, a linear energy dependence and a high mobility persisting up to energies much larger than the transport bandgap of the bulk. At higher energies, we observe multiple anomalous behaviors in conductance, charge metastability and Hall resistance that point towards the contribution of massive surface states in transport scattering and charge transfer to the bulk. The spectrum of these anomalies agrees with predictions of a phenomenological model of VP states in a smooth topological heterojunction. The model accounts for the finite interface depth, the effect of electric fields including the relativistic Dirac screening and predicts the energy of the first VP state. The massive surface states are a hallmark of topological heterojunctions, whose understanding is crucial for transport studies and applications.

*Speaker

Keywords: topological insulator, Dirac screenng, topological massive surface state

Visualisation de la supraconductivité hors équilibre

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Les supraconducteurs désordonnés se sont récemment révélés être des candidats idéaux pour la détection de photons. Jusqu'à présent seules des mesures de transport sur des échantillons macroscopiques ont été réalisées, révélant des anomalies électromagnétiques empêchant une détection optimale. Par ailleurs, la microscopie à effet tunnel (STM) est l'outil idéal pour cartographier les propriétés électroniques à l'échelle du nanomètre. Ainsi, la mise hors équilibre d'un nanofil supraconducteur grâce au courant injecté par la pointe du STM à différentes positions, intensités et polarisations sera comparée aux propriétés supraconductrices du nanofil mesurées par spectroscopie tunnel, dans le but d'accéder à l'efficacité locale de la brisure des paires de Cooper par l'injection de quasi-particules ainsi qu'à leur temps de recombinaison afin de mieux comprendre la dynamique des détecteurs de photons supraconducteurs.

Keywords: Supraconductivité désordonnée, Microscopie à effet tunnel, Supraconductivité hors équilibre

*Speaker

Reliable charge detection using cross-correlated shot noise in the fractional quantum Hall effect

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In the fractional quantum Hall (FQH) regime, excitations were predicted to carry fractional charge. To measure the charge of the carrier, a quantum point contact (QPC) coupling two chiral edge channels is used for partitioning. For a weak coupling, an incoming current I0 is nearly fully transmitted. In this regime, the quantum shot noise is expected to be proportional to the charge carrier.

Unambiguous measure of the fractional charge e*=e/3 at filling factor 1/3 using shot noise measurements were simultaneously done in 1997 by 2 groups. The Weizmann group (WG) used auto-correlation measurements at 60 mK while the Saclay group (SG) used cross-correlation measurements at 25 mK. However, later measurements done at lower temperature by the WG provided an unexpected doubling of the charge at filling factors 2/5 and 3/7.

We present here similar results when, starting from bulk filling factor 2/5, a local filling factor 1/3 is realized at the QPC. For a weak backscattering of the 1/3 state, auto-correlation gives a charge e* 2e/3 at low temperature and drops at e*=e/3 for higher (T> 100 mK) temperature, similarly to what was found by the WG. However, our experiments can also simultaneously perform cross-correlation measurements and the charge deduced from cross-correlation is found constant over temperature with e*=e/3.

At bulk filing factor 2/3, counter-propagating neutral modes have been used to explain the quasiparticles charge dependence over temperature. We will discuss evidences of co-propagating neutral modes in the 2/5 FQH state and the reliability of shot noise measurements using auto-correlation to determine the effective charge of carriers.

Keywords: fractional quantum Hall effect, shot noise, fractional charge

*Speaker

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Transient conductance between Fermi and Luttinger liquids

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We perform time dependent quantum transport simulations and semiclassical Boltzmann calculations
to study the conductance of quasi one-dimensional wires in the presence of electron-electron interactions.
While the intrinsic conductance of interacting one-dimensional systems is renormalized
by the interaction, it has been known for some time that this renormalization is washed out
by the presence of the (non-interacting) electrodes to which the wire is connected.
Here, we study the transient conductance of such a wire: a finite voltage bias is suddenly applied across the wire and we measure the current before it has enough time to reach its stationary value.
These calculations allow us to extract the Sharvin (contact) resistance of Luttinger and Fermi liquids.
In particular, we find that a perfect junction between a Fermi liquid electrode and a Luttinger liquid
electrode is characterized by a contact resistance that consists of half the quantum of conductance
in series with half the intrinsic resistance of an infinite Luttinger liquid.
Although the applied methods - a dynamical Hartree-Fock approach and a self-consistent Boltzmann
approach - are formally approximate, we find a perfect match
with the exact results of Luttinger/Fermi liquid theory.

Ref: T. Kloss, J. Weston, X. Waintal arXiv:1710.00895

Keywords: Luttinger liquid, Plasmons, Boltzmann approach

*Speaker

Spin dependant recombination dynamics in superconductors

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The aim of this work is to study the recombination dynamics of out-of-equilibrium spin polarized quasiparticle (QP) excitations in mesoscopic BCS superconductor with a spin-splitting field. The basic premise of the experiment is that, because the pairs are in the singlet state, the spin polarization will extend the lifetime of the excitation. Although the recombination dynamics in superconductors were studied as far back as the 70's, the experiments were performed in mm sized devices, with much lower QP densities and without spin, which makes revisiting the same phenomena in a mesoscopic superconductor with the inclusion of spin worthwhile.
The superconductor studied is a 6nm thick Al bar on a Si substrate, which allows for the application of an in-plane magnetic field up to _˜3T without killing superconductivity as well as reducing the phonon-pair breaking effects.
On top of this bar several tunnel contacts are fashioned: an NIS junction which serves as a quasiparticle injector; by applying a voltage between $\_\tilde{}\Delta - \mu\_BHand\_\tilde{}\Delta + \mu\_BHthespin -$
$polarizationoftheinjectedQPcurrentcanreachalmost 100\%, aswellasafewSISjunctionswhichserveasdetecto$
$IntheexperimentweseeevidenceofaspindependenceontheQPnumber/lifetimeontopofafielddependentdiffu$
$400nmwhichisincompatiblewithasimplethermalexcitation, whilethemeasurementofthedistributionfunction$

Keywords: quasiparticle recombination, relaxation dynamics, spin polarization, out of equilibrium superconductiviry

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*Speaker

Controlling Heat and Voltage of a Mesoscopic Contact

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- A fresh momentum to heat transport physics in nanostructure was recently given by a series of articles investigating heat currents in quantum channels. These experiment beyond measuring the quantum of heat flow of a single mode, proved the universality of this physical value. Going towards the manipulation of such heat modes would require to have a full characterization of the thermal conductance as function of the transmission of such channel. In the present talk I will present a new experimental setup that allows to control, separately and on demand, the temperature and the voltage of a floating ohmic contact. This new step opens the door for probing the heat conductance of a partially transmitted channel and will ease future implementations of heat engines in nanostructures.

Keywords: Thermal transport quantum Hall effect

*Speaker

Conductance and charge susceptibility of a double quantum dot

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We calculate the conductance and the charge susceptibility of a double quantum dot coupled to two metallic reservoirs both in equilibrium and nonequilibrium situations when a bias voltage is applied between the two reservoirs. This work is motivated by recent experiments carried out in Silicon-based double quantum dot probed by reflectometry techniques (A. Crippa et al., Nanoletters 2017). The calculations are performed by using the Non-Equilibrium Green Function (NEGF) method. In the non-interacting case, the conductance and the charge susceptibility is shown to exhibit peaks as a function of the the gate voltages Vg1 and VG2 applied to each dot, leading to a characteristic phase diagram of the system. We show how the method can be extended to the case of an interacting double quantum dot.

Keywords: double quantum, dot, non, equilibrium Green functions, quantum transport

*Speaker

Strongly pumped Josephson circuits

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Superconducting Josephson circuits are good candidates to implement quantum technologies, due to their long coherence times and strong couplings. An outstanding roadblock towards the emergence of large scale quantum devices, is the finite lifetime of the underlying qubits. One possible solution is to use the subtle interplay between coherent drives and nonlinear dissipation. One can then stabilize a manifold of quantum states in which we can encode, protect and manipulate quantum information. The efficiency of this protection scales with the drive strengths. In practice, this favorable scaling collapses for a critical drive strength. The purpose of this work is to understand this limitation, and design circuits which circumvent this breakdown.

Keywords: Superconducting circuits, reservoir engineering, cat qubits

*Speaker

Strongly pumped Josephson Circuits

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Superconducting Josephson circuits are good candidates to implement quantum technologies due to their long coherence times and strong couplings. An outstanding roadblock towards the emergence of large scale quantum devices, is the finite lifetime of the underlying qubits. One possible solution is to use the subtle interplay between coherent drives and nonlinear dissipation. One can then stabilize a manifold of quantum states in which we can encode, protect and manipulate quantum information. The efficiency of this protection scales with the drive strengths. In practice, this favorable scaling collapses for a critical drive strength. The purpose of this work is to understand this limitation, and design circuits which circumvent this breakdown.

Keywords: superconducting circuits, brightstate, transmon, cavity, Stark shift

*Speaker

Ballistic Magnetotransport of Weyl Fermions

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Weyl particles are chiral massless fermions: their existence was predicted in the 1920's by Hermann Weyl in the context of relativistic quantum mechanics. They have recently been observed as electronic excitations in solids. Their presence is associated with unusual transport properties, the most remarkable of them being a positive magnetoconductance. This anomalous magnetotransport has been related to a current between different Weyl valleys, a manifestation of the so-called Adler-Bell Jackiw, or chiral, anomaly. Existing studies have explored the magneto-transport within the linear diffusive response of Weyl particles under weak electric and magnetic field. Here we consider a different setup: the magneto-conductance of a short, voltage-biased Weyl junction in which electron transport is ballistic. We observe that at low fields quantum oscillations emerge in the conductance, before reaching a universal linear regime at high fields. Thus, we provide a simple setup to observe the manifestation of the chiral nature of Weyl fermions. Besides, our study proposes an experimentally relevant way to test its reality in Weyl materials, and sets an important step towards a unified understanding of anomalous transport in Weyl semimetals.

Keywords: Weyl/Dirac Semimetal, Ballistic transport, Magnetoconductance, Chiral Anomaly

*Speaker

Charge and energy transport in a Majorana nanowire

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Charge and energy transport in a Majorana nanowire

Keywords: Majorana

*Speaker

Nanofabrication using the Zeiss Orion He microscope

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The Zeiss Orion microscope is a focused He beam system. The source emitting the He ions is limited to a single W atome leading to a spot size on the sample to about 0,5nm. The tool is also equiped of a gaz injection system allowing a beam induced injection of W, Pt and SiO2. Several nanofabrication techniques can be perform with very high resolution:
Microscopy: high sensitivity to the surface and very large depth of focus.

Nanolithography: features below 10nm can be reproced

Direct etching: without contamination but a rather small yield compare to Ga

Beam induced deposition: high aspect ratio, linewidth below 20nm, without contamination
I will describe how operate this tool and give some examples of various objects we have realized so far.

Keywords: nanfabrication

*Speaker

The Josephson effect in Kitaev wires

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We study the Josephson effect in a superconducting ring based on the Kitaev chain. We propose an analytical method for computing the current flowing along the ring, and show that it exhibits an anomalous periodicity with respect to the magnetic flux threading the loop, also known as the 4pi Josephson effect. This anomalous periodicity is related to the presence of Majorana bound states at the edge of the superconductor, and to the transfer of single- electron instead of charge 2e Cooper pairs. It is an experimentally accessible signature of the presence of Majorana fermions in one-dimensional systems.

Keywords: Kitaev wire, Majorana fermions, Josephson effect

*Speaker

Extracting single electron wavefunctions from a quantum electrical current

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Quantum nanoelectronics has entered an era where quantum electrical currents are built from single to few on-demand elementary excitations. To date however, very limited tools have been implemented to characterize them. In this work, we present a quantum current analyzer able to extract single particle excitations present within a periodic quantum electrical current without any a priori hypothesis. Our analyzer combines two-particle interferometry and signal processing to extract the relevant electron and hole wavefunctions localized around each emission period and their quantum coherence from one emission period to the other. This quantum current analyzer opens new possibilities for the characterization and control of quantum electrical currents in nanoscale conductors and for investigations of entanglement in quantum electronics down to the single electron level.

Keywords: quantum signal processing, electron quantum optics, quantum transport

*Speaker

Majorana excitations induced by defects in two-dimensional topological superconductors with spin-orbit coupling

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Recent microscopy experiments on superconducting monolayer of lead (Pb) grown over clusters of cobalt atoms have raised urgent questions about robust in-gap electronic states in presence of strong spin-orbit coupling and magnetism. Thus motivated we theoretically study relevant models of two-dimensional s-wave superconductors with fixed configurations of magnetic field and Rashba spin-orbit coupling. Using both analytical approaches and exact diagonalization techniques we find that a vortex defect in Rashba coupling binds a Majorana mode, but in contrast to a typical superconducting vortex, such defect does not exhibit a tower of in-gap excited states. We present these results and try to relate them to puzzling aspects of recent unpublished microscopy experiments. We also study superconducting vortices in mixed singlet-triplet topological superconductors, introducing the notion of topological protection of multiple Majorana modes. Finally, we discuss the possibility of multiple Majorana states bound to magnetic textures in such superconductors.

Keywords: Majorana, topological superconductivity, Rashba spin orbit coupling, vortex, triplet superconductor, two, dimensional superconductor

*Speaker
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Towards large scale spin based quantum information processing in semiconductors

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Owing to the recent demonstration of very coherent qubit operations in purified silicon, an important effort is nowadays invested in semiconductors both in the academic and in the industrial worlds to face the challenges of large scale spin based quantum information processing. From a comparative point of view and considering the impressive overhead in the number of qubits from the implementation of quantum error correction codes, spin qubits have several advantages that need to be validated in qubit architecture for large scale quantum computation: their size and their immediate compatibility to advanced CMOS technology. I will review this effort with first the description of the different carriers of quantum spin information (nuclei, electron, holes) in semiconductor structures, how to control and measure them, their main characteristics and their figure of merits. I will describe then the challenges to control and couple them at large scale, the envisioned architectures to realize topological error correction codes and their advantages.

Keywords: Spin qubits

*Speaker

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Cross-channel electron waiting times of a multi-terminal scatterer

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We investigate the cross-channel electron waiting time distribution (WTD) of systems with multiple transport channels and terminals. The position of the detectors and multiple times in each channel are considered. Based on previous work [1, 2], using a scattering matrix formalism, we obtain generalized expressions for the electron idle time, the first passage time, and the waiting time distribution functions in compact forms.
We apply our theory to an electron beam splitter based on a quantum point contact (QPC) setup, where the incident electron wave packages can be either reflected or transmitted into different output channels with finite probability. We evaluate the distribution of waiting times between detections in each output channel. Our work shows that the zero-point of the cross-channel WTD is shifted with respect to the relative position of the detectors. This suppression is a direct consequence of the Pauli exclusion principle, where a electron can only occupy one transport state in either reflection or transmission channel at a given time. We are currently investigating WTDs in more complicated situations with multiple input and output channels such as spin-dependent scattering processes and Andreev reflections in superconducting systems [3]

References:

G. Haack, M. Albert, and C. Flindt, ”Distribution of electron waiting times in

quantum-coherent conductors”, Phys. Rev. B 90, 205429 (2014).

D. Dasenbrook, P. P. Hofer, and C. Flindt, ”Electron waiting times in coherent

conductors are correlated”, Phys. Rev. B, 91, 195420 (2015).

S. Mi and C. Flindt, in preparation (2017)

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Keywords: waiting time distribution, beam splitter, coherent transport

Edge states and Dirac cones in Orbital Graphene

Marijana Milicevic *† [1], Tomoki Ozawa [2], Gilles Montambaux [3], Iacopo Carusotto [2], Aristide Lemaitre [4], Luc Le Gratiet [5], Isabelle Sagnes [5], Jacqueline Bloch [6], Alberto Amo [6]

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(Abstract)

Exciton polaritons are mixed light-matter particles arising from the strong coupling of quantum well excitons and cavity photons in semiconductor microcavities. Thanks to the direct visualisation of their dispersion and spatial eigenfunctions in luminescence experiments, and to the possibility of designing the photonic potential landscape, they provide an extraordinary photonic platform to emulate 1D and 2D Hamiltonians, and to engineer Hamiltonians with novel transport properties.

A Hamiltonian of particular interest is that of electrons in graphene. We have fabricated a honeycomb lattice for polaritons consisting of coupled micropillars (figure 1). The lowest two bands of this structure arise from the coupling of the lowest energy modes of each micropillar and emulate for photons the π and π^* bands of graphene [1], showing two non-equivalent Dirac cones and flatband states localised both in zigzag and bearded edges [2].

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cones and flatband states localised both in zigzag and bearded edges [2].

Remarkably, our system permits exploring orbital degrees of freedom, inaccessible in actual graphene. Higher orbital bands originate from coupling of the first excited modes of micropillars, giving rise to a novel type of dispersive edge bands [3]. Our photonic simulator allows the manipulation of the orbital band structure and the edge states by tuning the geometry of the honeycomb lattice. In this way we are able to observe experimentally the two universal kinds of fusion of Dirac cones that exist in 2D systems.

Our platform presents interesting perspectives in view of studying microscopic properties of orbital edge states and their connection to the topological properties of orbital bulk bands, as well as nonlinear Dirac physics owing to polariton-polariton interactions.

T. Jacqmin, I. Carusotto, I. Sagnes, et al., Phys. Rev. Lett. **112**, 116402 (2014)

M Milićević T. Ozawa, P. Andreakou et al., 2D Mater. **2**, 034012 (2015)

M Milićević T. Ozawa, G. Montambaux et al., Phys. Rev. Lett. **118**, (2017)

(Resume court)
Exciton polaritons are mixed light-matter particles that provide an extraordinary photonic platform to emulate 1D and 2D Hamiltonians. We have fabricated a honeycomb lattice for polaritons consisting of coupled micropillars. The lowest two bands of this structure arise from the coupling of the lowest energy modes of each micropillar and emulate for photons the π and π^* bands of graphene, showing two non-equivalent Dirac cones and flatband states localised both in zigzag and bearded edges. Remarkably, our system permits exploring orbital degrees of freedom, inaccessible in actual graphene. Higher orbital bands originate from coupling of the first excited modes of micropillars, giving rise to a novel type of dispersive edge bands. Our photonic simulator allows the manipulation of the orbital band structure and the edge states by tuning the geometry of the honeycomb lattice. In this way we are able to observe experimentally the two universal kinds of fusion of Dirac cones that exist in 2D systems.

Keywords: graphene, polaritons, etats de bord, cones de dirac

Noise of a chargeless Fermi liquid

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We develop a Fermi liquid theory to describe transport in a superconductor-quantum dot-normal metal junction close to the singlet-doublet (parity changing) transition of the dot. Though quasiparticles do not have a definite charge in this chargeless Fermi liquid, in case of particle-hole symmetry, a mapping to the Anderson model unveils a hidden U(1) symmetry and a corresponding pseudo-charge. In contrast to other correlated Fermi-liquids, the back scattering noise reveals an effective charge equal to the charge of Cooper pairs. In addition,we find a strong suppression of noise when the linear conductance is unitary, even for its non-linear part.

Keywords: Superconductor, quantum dot system, Kondo effect, Shiba state, Fermi liquid theory

*Speaker

Coherent control of individual electron spins in a two-dimensional array of tunnel-coupled quantum dots

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Controlling nanocircuits at the single electron spin level is a promising route for large-scale quantum information processing. In this context, individual electron spins have been identified as versatile quantum information carriers to interconnect different nodes of a spin-based semiconductor quantum circuit. The cumulated efforts to finely control individual electron spins in linear arrays of tunnel-coupled quantum dots have permitted the recent realization of quantum simulators. However, the two-dimensional scaling of such control required to implement the envisioned quantum computer architectures remains a challenge. Here, we demonstrate such two-dimensional coherent control using individual electron spins in a 3x3 array of tunnel-coupled quantum dots. We show that the electron spin coherence can be maintained over 10 um and 600 ns when the two electrons of the singlet-triplet qubit are displaced. This work paves the way for the physical implementation of a scalable quantum computer architecture.

Keywords: Quantum dots, Scalability, Spin qubit

*Speaker

Phase dependent microwave absorption of a bismuth nanowire based Josephson junction : revealing topological Andrev level crossings.

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Topological insulators are materials that have electronic states located at their edges, which are protected against backscattering by time reversal symmetry. Bismuth, a semi-metal with strong spin-orbit coupling, was predicted to be topological in the case of a bilayer-thick crystal [1]. We showed numerically that edge states still exists in Bi nanowires, and experimentally demonstrated the existence of edge conduction channels as well as their ballisticity in a recent work, by embedding the nanowire into an asymetric SQUID [2]. The goal of the present experiment is to go one step further and to quantify the topological protection against backscattering as well as the lifetime of the metastable Andreev bound states formed in these topological S/Bi/S junctions.

This is done by inductively coupling the Bi/S loop to a multimode superconducting resonator, with eigenfrequencies ranging from 300 MHz up to 6 GHz, and measuring the magnetic flux-dependent absorption at each of these frequencies [3]. The resulting phase-dependent absorbtion spectrum is measured for different temperatures and can be analyzed using a simple low-energy hamiltonian taking into account two Andreev bound states that almost do not anticross, in agreement with a topological protection [4].

S. Murakami, Phys. Rev. Lett. 97 (2006)

A. Murani et. al., Nat. Comm (2017)

B. Dassonneville et. al., PRL (2013)

A. Murani et. al., PRB (2017)

Keywords: Bismuth, nanowires, topology, edge states, asymetric SQUID

*Speaker

Magnetic field driven ambipolar quantum Hall effect in epitaxial graphene close to the charge neutrality point

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Graphene offers an excellent platform for quantum Hall effect (QHE) physics due to the large energy separation between Landau levels. We will present here a study of the QHE in graphene grown on Silicon-terminated face of Silicon Carbide (SiC) at low doping. Graphene on SiC demonstrated its potential for fundamental physics (renormalization of the Fermi velocity) and applications (electrical metrology). The SiC substrate influences dramatically the structural and electrical properties of graphene. In particular, charge transfer takes place between graphene and the SiC/Graphene interface. Due to the complexity to design transistor configurations without degrading the quality of this type of graphene, few transport measurements at low doping and under magnetic field have been reported.
Here, we will present magnetotransport measurements on graphene on SiC near the charge neutrality point (CNP) which allowed us i) to quantify the disorder [1], ii) to demonstrate an anomalous ambipolar behavior of the Hall magnetoresistance explained in terms of an asymmetry of disorder [1], and iii) to observe giant non-local resistances under magnetic field [2] (reported only for graphene on SiO2 or BN to date).

First, we tune the carrier density of graphene Hall bars by means of a Corona discharge method. Then, the influence of disorder is evaluated close to the CNP by various methods based on transport measurements: i) at room temperature, the dependence of the resistivity on the Hall coefficient is analyzed; ii) by fitting the temperature dependence of the classical Hall coefficient; iii) by fitting the magnetoresistances at low temperature. All methods converge to give disorder of amplitude 20 meV.

Because of this relatively low disorder, unusual features of the QHE are observed. The most striking is a sign change of the Hall magnetoresistance as a function of magnetic field. The Hall resistance first becomes negative (hole type), but at higher magnetic field cancels and eventually stabilizes on a positive quantum Hall plateau (electron type). When the Hall resistance cancels, the longitudinal resistance shows a clear maximum. The usual Drude model fails to explain the data. By contrast, data are better explained by assuming an asymmetry of the disordered density of states (DOS) at the CNP. Although a shift of the position of the quantum Hall plateaus have been reported previously in two-dimensional electron gases [3], the effect appears more dramatic in graphene because of the ambipolar nature of this material. Possible microscopic origin of this asymmetric disorder will be mentioned with a model reproducing qualitatively the

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experimental results.

Finally, non-local transport measurements have been systematically done on these devices. A current is circulating between two hall contacts while the voltage is measured on the other Hall pads of the bar (hence outside the classical current path). Very large non-local resistances are observed when the Fermi energy crosses the CNP in the presence of alarge out-of-plane magnetic field. Ongoing analysis (based on previous results on graphene on SiO2 [4]) allow us to demonstrate an extremely weak contribution of spin effects, but are only partially explained by thermoelectric effects at this step.

References

A. Nachawaty, M. Yang, W. Desrat, S. Nanot *et al.*, Phys. Rev. B **96**, 075442 (2017)

Nachawaty, *et al., under prep.*

R. Haug, R. Gerhardts, K. v. Klitzing and K. Ploog, Phys. Rev. Lett. **59**, 1349 (1987)

J. Renard, M. Studer, and J. A. Folk Phys. Rev. Lett. **112**, 116601 (2014)

Keywords: graphene, integer Quantum Hall effect, Non local resistance

Superconducting quantum refrigerators

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I discuss our current efforts - both theoretical [1,2] and experimental [3] - on quantum refrigerators based on superconducting qubits. We demonstrate that quantum coherences influence heat transport in these systems. [1] B. Karimi and J. P. Pekola, Phys. Rev. B 94, 184503 (2016). [2] A. Ronzani et al., in preparation (2017).

Keywords: Thermodynamics and heat transport at the nanoscale

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Theory for Hybridized Andreev States: The Andreev Molecule

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In Josephson junctions, the coupling of two superconductors leads to the formation of Andreev Bound States (ABS) at the interface. They are two-level systems, or artificial atoms, which can be used, for example, to encode quantum information.
ABS are localized Cooper pairs whose wave functions extend over a few superconducting coherence length ξ. If two junctions are separated by a distance d $\sim \xi$, the overlap of ABS wave-functions can lead to the formation of an artificial molecule, or Andreev molecule. Such hybridized Andreev states have originally been referred to as "quartet" states [1].

The Andreev molecule forms through two non-local microscopic mechanisms: (i) elastic cotunneling of Cooper pairs and (ii) crossed-Andreev reflection. Due to these processes, a current flowing through one of the junction depends on the phase across the other one, leading to a non-local Josephson effect. This allows, for example, engineering a ϕ-junction using only conventional materials. In such junction, a supercurrent can flow even in absence of superconducting phase difference across it, a property that could be used for the realization of a phase-battery, a memory cell or a qubit.

In order to detect and manipulate Andreev molecules, we propose experiments relying on state-of-the-art techniques of nano-fabrication, and standard DC and microwave measurements.
Freyn et al. Phys. Rev. Lett. 106, 257005

Keywords: Andreev molecule

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Observation of Volkov-Pankratov states in topological HgTe heterojunctions using RF compressibility

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It is well established that topological insulators sustain Dirac fermion surface states as a consequence of band inversion in the bulk. These states have a helical spin polarization and a linear dispersion with large Fermi velocity. In this article we report on a set of experimental observations supporting the existence of additional massive surface states. These states are also confined by

the band inversion at a topological-trivial semiconductor heterojunction. While first introduced by Volkov and Pankratov (VP) before the understanding of the topological nature of such a junction, they were not experimentally identified. Here we identify their signatures on transport properties at high electric field. By monitoring the AC admittance of HgTe topological insulator field-effect

capacitors, we access the compressibility and conductivity of surface states in a broad range of energies and electric fields. The Dirac states are characterized by a compressibility minimum, a linear energy dependence and a high mobility persisting up to energies much larger than the transport bandgap of the bulk. At higher energies, we observe multiple anomalous behaviors in conductance, charge metastability and Hall resistance that point towards the contribution of massive surface states in transport scattering and charge transfer to the bulk. The spectrum of these states agrees with predictions for VP states within a phenomenological model of a smooth topological heterojunction. The model accounts for the finite interface depth, the effect of electric fields including Dirac screening and predicts the energy of the first VP state. The massive surface states are a hallmark of topological heterojunctions, whose understanding is crucial for transport studies and applications.

Keywords: Topological insulator, HgTe, Dirac state, compressibility, massive states

*Speaker

Quantum microwaves with a DC-biased Josephson junction

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Tunneling of a Cooper pair through a dc-biased Josephson junction is possible only if collective excitations (photons) are produced in the rest of the circuit to conserve the energy. The probability of tunneling and photon creation, well described by the theory of dynamical Coulomb blockade, increases with the coupling strength between the tunneling charge and the circuit mode, which scales as the mode impedance. Using very simple circuits with only one or two series resonators, we first show the equality between Cooper pair tunneling rate and photon production rate [1]. Then we demonstrate a strong coupling regime for which the presence of a single photon blocks the next tunneling event and the creation of a second photon [2]. Finally, using two resonator with different frequencies, we demonstrate photon pair production [3], two-mode squeezing, and entanglement between the two modes leaking out of the resonators. [1] M. Hoffheinz et al., Phys. Rev. Lett. 106, 217005 (2011) [2] In preparation [3] M. Westig et al., Phys. Rev. Lett. 119, 137001 (2017)

Keywords: microwave quantum optics

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Finite Energy Relaxation in the Integer Quantum Hall Regime

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Since a decade, it is possible to realize in condensed matter, quantum optic like experiment with electrons instead of photons. The ballistic beam like motion of the electrons is obtained in the Integer Quantum Hall (IQH) regime induced in a high mobility two dimensional electron gas. In such a regime the charge transport occurs through one dimensional chiral wires localized on the edge of the sample: the edge states.
We investigate the energy relaxation of electrons injected at a well defined energy above the Fermi sea in the edge states. The energy of the injected electrons is selected with a first Quantum Dot used as an energy filter by manipulating its discrete energy levels. After a propagation length of a few μ-meters, where relaxation mechanisms can take place, a second Quantum Dot is used to detect the energy at which electrons arrive. This experiment provides the first accurate spectroscopy of the relaxation of quasiparticles in the IQH regime.

Recently the spectroscopy of quasiparticle was achieved employing the two Quantum Dots with a propagation length of 0.75μm, injecting electrons above the Fermi sea at the selected energy with an uncertainty _˜15μeV. Preliminary results show that even on this short propagation length a considerable amount of the injected electrons relaxes toward a hot electron regime while most of them were detected on the process of relaxation in a non Fermi distribution. However few of the electrons don't relax and were observed at the injected energy (up to 145μeV).
This in-progress experiment may shed light on the nature of quasiparticles and their interactions in quantum Hall edge channels.

Keywords: Quantum Hall Effect, Edge States, Energy Relaxation

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Strongly correlated electron transport in CMOS silicon quantum dots

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Quantum shot noise reflects the granularity of charge transfers in quantum conductors, allowing to probe their dynamics. We have performed high-sensitivity shot noise measurements in quantum dots obtained in CMOS Silicon nanowires. Our results show significant increase in the Fano factor in the *inelastic* cotunneling regime, with values larger than 1, corresponding to highly-correlated, non-Markovian charge transfer processes. Surprisingly, when the quantum dot is more open, we observe similar super-Poissonian values of the Fano factor in the *elastic* cotunneling regime, which is not predicted by theory.

Keywords: quantum dot, shot noise, quantum transport

*Speaker

Universal theory for out-of-equilibrium transport: application to driven Josephson junctions.

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We aim to present some aspects and applications of a universal out-of-equilibrium perturbative theory1 with respect to a Hamiltonian whose time-dependence (TD) can be periodic2 or not, and controlled through external TD or fluctuating fields. The Hamiltonian terms are all arbitrary, and are required to ensure merely one condition. Such a theory covers a large domain of physical problems, and has been useful in numerous theoretical and experimental works,3 some of which have tested directly some of the theorems it led too.4 It has also allowed us to revisit the implementation of minimal excitations in non-linear systems.5 In the stationary regime, it generalizes to a large extent the Rogovin-Scalapino formula for out-of-equilibrium noise, and provides its version in case the current average is not symmetric.
We will focus on its relevance to Josephson junctions (JJs) coupled strongly to an electromagnetic environment in both dual limits : EJ< > Ec, where EJ and Ec are the Josephson and charging energies. A recent work by A. Di Marco, F. Hekking with G. Rastelli, modelling the regime EJ> > Ec through " phase particle " tunneling, has recovered our theorem for the average voltage, through its explicit calculation. We show that the theory alllows us to go further : it provides the out-of-equilibrium admittance and voltage fluctuations at zero or finite frequencies. In particular, the expression of zero-frequency voltage noise, having a quadratic behavior at low bias, has been tested experimentally in Ref.8.

1- I. Safi, "Time-dependent Transport in arbitrary extended driven tunnel junctions" arXiv:1401.5950. I. Safi, " Universal perturbative theory for periodic or non-periodic driving. Part I: Probing ratchet effects and using them as probes. ", submitted to Phys. Rev. B.

2- I. Safi and E. Sukhorukov, "Determination of tunneling charge via current measurements", Eur. Phys. Lett. 91, 67008 (2010). B. Roussel, P. Degiovanni et I. Safi, " Perturbative fluctuation dissipation relation for non-equilibrium finite frequency noise in quantum circuits " Phys. Rev. B 93, 045102 (2016)

3-M. Hofheinz *et al.*, " The bright side of Coulomb Blockade ", Phys. Rev. Lett. 106, 217005 (2011). S. Jebari et al, arXiv:1704.04432 (2017).

4-C. Altimiras et al. "Dynamical Coulomb Blockade of Shot Noise" Phys. Rev. Lett. 112, 236803 (2014). O. Parlavecchio, C. Altimiras, J.-R. Souquet, P. Simon, I. Safi, P. Joyez, D. Vion, P. Roche, D. Estève, and F. Portier, "Fluctuation-dissipation relations of a tunnel junction driven by a quantum circuit", Phys. Rev. Lett. 114, 126801 (2015)

5- J. Keeling *et al*, Phys. Rev. Lett. 97,116403 (2006). J. Dubois et al. Nature 502, 659

*Speaker

(2013).

6-A. Di Marco, F. W. J. Hekking, and G. Rastelli, Phys. Rev. B 91, 184512 (2015).

7-I. Safi, in "Noise and Fluctuations", AIP Conference Proceedings of XX Int. Conf. on Noise and Fluctuations (Pisa 2009), 1129, ed. M. Macucci and G. Basso (AIP, Melville, New York, 2009). I. Safi and P. Joyez, Phys. Rev. B 84, 205129 (2011).
8- J-Y Wang, T-H Chung, T-H Lee, and C-D Chen , " Quadratic Characteristics of Environment Induced Voltage Shot Noise in Josephson Junctions ", Scientific Reports 7 :3567 (2017)

Keywords: Transport hors, équilibre, Jonctions Josephson, Circuits quantiques, Bruit haute fréquence

Collision of interacting voltage pulses under Ehrenfest dynamics

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We study the effects of perpendicular collision between two collimated voltage pulses traveling through a four-terminals mesoscopic quantum dot. We consider time scales smaller then the Ehrenfest time in order to obtain quasi-classical dynamics. Electron-electron interactions are taken into account under the dynamical Hartree-Fock approach[1]. We use numerical methods based on recently available time-resolved techniques to solve efficiently the nonlinear Schroedinger equation[2]. We analyze the system dynamics by the local time-dependent current and charge density. A simplified analytical model to the pulses collision is let to a future step.

T. Kloss, J. Weston and X. Waintal. "Transient conductance between Fermi and Luttinger liquids". ArXiv:1710.00895 (2017)

B. Gaury, J. Weston, M. Santin, M. Houzet, C. Groth and X. Waintal, "Numerical simulations of time-resolvedquantum electronics," Phys. Rep. 534, 1 (2014).

Keywords: time, dependent quantum transport, voltage pulses, scattering theory, electron, electron interaction

*Speaker

Spectroscopy of a plasomic cavity using electronic transport measurement

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Placed in a cavity, a molecule presenting some dipolar momentum, can interact strongly with the electromagnetic field of the cavity, giving rise to new states for the system mixing light and matter. This phenomenon, called the Rabi splitting, is furthermore enhanced by the number of dipoles in the cavity. Experimentally, to see those states, people have built optical cavities with quiet high quality factor at low temperature and measured the absorption spectrum of the device. Some recent experiments have been done in plasmonic nano cavities at room temperature, showing that strong coupling for a single molecule can be achieved in such devices at the cost of a low quality factor. Considering the size of the device we can imagine replacing the upper part of the cavity by a STM tip allowing transport through the dipole. Doing so and measuring the current flowing through the molecule one can do the spectroscopy of the cavity by studying the jumps in the current. We propose a theoretical study of this kind of setup, computing the current going through a dipole in a nano cavity in the sequential tunnelling regime using a rate equations approach.

Keywords: quantum transport

*Speaker

Theory of coherent quantum phase-slips in ingomogeneous superconducting wires or Josephson junction chains

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We study coherent quantum phase-slips, which lift the ground state degeneracy in a superconducting loop made of a thin metallic wire or a Josephson junction chain, pierced by a magnetic flux, whose magnitude is equal to half of a flux quantum. The quantum phase-slip amplitude is sensitive to the normal mode structure of superconducting phase oscillations in the loop (Mooij-Sch́on modes). These, in turn, are afected by long-range spatial inhomogeneities in the loop. We analyze the case of weak periodic modulations of the system parameters as well as weak random modulations, and derive the corresponding modication of the quantum phase-slip amplitude.

Keywords: one, dimensional superconductors, phase, slips

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Artificial electronic superlattices as platforms for probing robustness of non-trivial topology

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A new trend of research in condensed matter consists in engineering the properties of materials. From photonic crystals to origami based mechanical metamaterials, researchers have designed artificial structures where the optical, magnetic and mechanical properties can be changed as they wish. Until recently, artificial electronic systems have not been investigated due to the fact that they require patterning at the nanometer scale, which was experimentally extremely challenging. In this presentation, we will focus on self-assembled nanocrystal superlattices. These artificial electronic systems exhibit many interesting features such as Dirac cones, flat bands and room-temperature non-trivial topological gaps. After an introduction on the state of the art, we will emphasize how these materials can be used as a platform to study fundamental physics questions. As an example, we will show a recent theoretical study on the robustness of the helical topological edge states in two-dimensional topological insulators. Indeed, if one takes a flake of those systems, large orbital magnetic moments arise. These magnetic moments can be used as a probe to non-trivial topology. We will also discuss how the strength of a non-trivial gap against disorder not only depends on its bandwidth, but on the overall bandstructure of the considered system. This feature is clearly seen thanks to magnetic moments behavior. Finally, we will address a few words on the experimental feasibility of such studies.

Keywords: Superstructures, Topology, Magnetic Moments, Disorder

*Speaker

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Physics of electron g-factors in semiconductor nanostructures

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The manipulation of the electron spin in semiconductor nanostructures requires the knowledge of the electron g-factor. In this work, we revisit the physics of the electron g-factor in nanostructures of various shape, size, dimensionality (0D-3D) and composition. Our investigation is based on a combination of atomistic and analytical calculations. We show that, for a given compound, the electron g-factors follow a universal law that just depends on the energy gap, in particular along rotational symmetry axes. We demonstrate that the orbital magnetic moment density strongly depends on the shape of the nanostructure but the total (integrated) magnetic moment is independent of the shape and therefore of the electron envelope wavefunction. The physical origin of this non-trivial behavior is explained. We deduce that the bulk component of the g-factor is isotropic and that g-factor anisotropies entirely come from surface effects.

Keywords: g factor, spin orbit coupling

*Speaker

Quasiparticle dynamics in Andreev quantum dots

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In contrast with a bulk superconductor, a single-channel phase-biased superconducting weak link hosts a discrete subgap quasiparticle state, called "Andreev state". As such, it can be seen as a sort of quantum dot in which zero, one or two quasiparticles can be trapped, not due to electrostatic barriers, but to the phase drop. This "Andreev quantum dot" constitutes a very simple playground to explore the foundations of mesoscopic superconductivity.
I will present experiments on Andreev quantum dots obtained at one-atom contacts between aluminum electrodes, in which we probe the dynamics of quasiparticles trapping and un-trapping using circuit-QED like techniques [1]. I will focus in particular on the effect of the cavity on this dynamics.
C. Janvier *et al.*, Science **349**, 1199 (2015)

Keywords: Andreev States, cQED, quasiparticle dynamics

*Speaker

Experiments to measure hybridized Andreev bound states at zero voltage

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Andreev Bound States (ABS) are localized quasiparticle states formed at a weak link between two superconductors. These states extend over a distance ξ, the superconducting coherence length. The Andreev Bound States in two separate Josephson junctions can couple and hybridize if the distance between the junctions d is less than or comparable to ξ. In such bi-junction systems, the supercurrent through one junction is modied by the phase dierence of the other junction. Finitevoltage measurements on nanowire based proximity bi-junctions has shown coupling between ABS [1] but a non-local supercurrent or current-phase relation has not yet been established.
A drawback of nite-voltage measurements on bi-junctions is that non-local eects can also result from a parasitic electromagnetic coupling. We demonstrate this with a control experiment on tunnel bi-junctions where resonances similar to hybridized ABS persist even when the distance between the junctions exceeds ξ.
On the contrary experiments on bi-junctions at zero voltage should provide clear signatures of hybridized Andreev Bound States. We propose circuits to measure the energy spectrum, non-local supercurrent and current-phase relation in closely spaced bi-junctions comprising a few transparent conduction channels. We explain how to satisfy the experimental constraints with an unconventional fabrication process and present preliminary results on these devices..

Keywords: andreev bound states, hybridization, non local supercurrent, josephson junction

*Speaker

Will quantum error correction save the quantum computer?

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Quantum computers hold the promise of an exponential speed up of certain tasks with respect to classical computers. In this talk, I will review how such speed up is achieved and what it implies on the specifications that are required for the manipulation of the quantum states. I will stress that a quantum computer is inherently an analogue machine — its internal state is described by continuous variables — and that its computing power is not only set by its size but chiefly by its precision. Precision deteriorates with the number of operations; it is the chief resource of a quantum computer that sets the complexity of possible calculations. In the second part, I will discuss quantum error correction schemes that propose, to some extend, to trade precision with size: using several qubits, one can build a better, more precise, logical qubit. In theory, quantum error correction solves the problem of the extreme precision that is required by even the simplest realistic applications of quantum computing. In practice, quantum error correction implies massive overheads that make its applicability doubtful.

Keywords: Quantum error correction

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Strong spin-orbit interaction in graphene induced by transition metal dichalcogenides

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Spin-orbit interaction (SOI) plays a crucial role to generate drastically new concepts of materials or phenomena in recent condensed matter physics. While importance of SOI has been intensively discussed in many materials, there still remains a novel material where SOI has not been well exploited yet; graphene. Due to the small atomic number of carbon graphene has weak SOI, but strong SOI in graphene can drive the system into two dimensional topological insulators, and also make itself intriguing in spintronics. Attempts to enhance SOI of graphene have just begun: Heterostructures of graphene with transition metal dichalcogenides (TMDs) are especially promising because it can enhance SOI of graphene with its unique band structure intact, and several theoretical and experimental studies were reported. However, while TMDs have different band structures between monolayer and bulk, theoretical studies focus on monolayer TMDs as a source for SOI, whereas almost all experimental reports have exploited multilayer TMDs. No studies have reported on direct comparison between monolayer and bulk TMDs for the efficient generation of strong SOI in graphene. It is also significant to consider the symmetry of the induced SOI to realize the quantum spin Hall effect (QSHE) in graphene. Nevertheless, it was not intensively discussed in previous studies and some of them completely neglected this point.
In this talk we show a strong SOI induced in graphene by several different TMDs (MoS2, WS2 and WSe2). Starting from the observed signatures of the strong SOI induced in graphene by monolayer MoS2 and bulk WSe2 via magnetotransport measurements, we especially focus on the results obtained from monolayer and bulk WS2. Both systems enhance SOI of graphene largely, but also we found a striking difference between monolayer and bulk WS2. Drastically different shapes of weak-antilocalization (WAL) curves observed in graphene/monolayer WS2 (G-mono) and graphene/bulk WS2 (G-bulk) demonstrate that monolayer WS2 can induce much stronger SOI in graphene, and theoretical analysis of the experimental results show the induced SOI is more than 10 meV for the G-mono samples while it is less than 1 meV in the case of G-bulk samples.

The symmetry of the induced SOI is also discussed in detail. Two types of SOI with different symmetry are possible in our system: One is symmetric in z to –z inversion, where z is the axis normal to the graphene plane, and the other is asymmetric in the inversion. Dominant Kane-Mele type SOI included in the symmetric SOI is required for the QSHE. Using the experimental results and the fitting function which includes both symmetric and asymmetric spin-orbit time, we found that symmetric SOI should be much stronger then asymmetric SOI to explain the experimental results, promising to realize the QSHE in graphene.
Finally, we report anomalous temperature dependence of the resistance of graphene on monolayer WS2. Resistance of pristine graphene is known to be weakly dependent on temperature,

*Speaker

and similar temperature dependence was observed for the G-bulk samples. On the other hand, surprisingly, G-mono samples exhibit strong increase of the resistance with decreasing temperature, and the value of resistance at 77 K is almost a factor of three larger than that at room temperature. Below 77 K, the resistance is almost constant. This anomalous temperature dependence of the resistance shows strong coupling between graphene and monolayer WS2, and is suggestive of existence of spin-orbit gap for the bulk state around the Dirac point. Moreover, the saturation of the resistance at low temperatures indicates the existence of a small number of residual conducting states inside the gap.

Keywords: Spin, orbit, graphene, transition metal dichalcogenide

Scanning gate microscopy: from strongly to weakly invasive probes

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Scanning gate microscopy images from measurements made in the vicinity of quantum point contacts were originally interpreted in terms of current flow. Though some recent work has analytically connected the local density of states to conductance changes in cases of perfect transmission of circumstances, there are important deviations that are highly sensitive to imperfect transmission. Nevertheless, the unperturbed partial local density of states can be extracted from a weakly invasive scanning gate microscopy experiment, provided the quantum point contact is tuned on a conductance plateau [1]. However, the quality of the extracted partial local density of states decreases with increasing tip size and strength.

In order to experimentally explore the transition from strongly invasive scanning gate microscopy to the perturbative regime of weak tip-induced potentials, an open resonator is fabricated in a two-dimensional electron gas [2]. With the help of numerical simulations that reproduce the main experimental findings, we quantify the extent of the perturbative regime in which the tip-induced conductance change is unambiguously determined by properties of the unperturbed system. We analyze the characteristic length scale and the amplitude modulation of the conductance change. In the perturbative regime, the former is shown to assume a disorder-dependent maximum value, while the latter linearly increases with the strength of a weak tip potential.

"Partial local density of states from scanning gate microscopy", Ousmane Ly, Rodolfo A. Jalabert, Steven Tomsovic, and Dietmar Weinmann, Phys. Rev. B 96, 125439 (2017)

"Scanning gate experiments: from strongly to weakly invasive probes", Richard Steinacher, Christina P´oltl, Tobias Kr´ahenmann, Andrea Hofmann, Christian Reichl, Wilhelm Zwerger, Werner Wegscheider, Rodolfo A. Jalabert, Klaus Ensslin, Dietmar Weinmann, and Thomas Ihn, arXiv1709.08559

Keywords: quantum transport, scanning gate microscopy

*Speaker

A semiclassial approach for the spectrum of a voltage-biased three termial Josephson junction

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We study a Josephson junction system with three terminals coupled through a quantum dot. Two of the terminals are applied with opposite voltage biases with the third as the reference of ground. In the limit of small voltage bias, a semiclassical method is established as the voltage plays the role of the Planck constant in WKB approximation. The tunneling effects between the two Wannier-Stark ladders is studied in the limit when superconducting gap is infinite. When the two ladders resonate, an amplification of the perturbation appears, showing a stronger influence of one ladder to another at resonance. Later the infinite gap assumption is lifted and the coupling to continuum is reimposed. The transition of our semiclassical solution at the superconducting gap is beyond the semiclassical approach. A toy model is employed to study the effect of such kind of transition. We find this will introduce an exponentially small imaginary part to the denominator of the resolvent, giving a source of dissipation in this half-open system.

Keywords: Josephson junction, WKB approximation, Wannier Stark ladder

*Speaker

Synthetic spin orbit interaction for Majorana devices

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The engineering of Majorana modes in condensed matter systems could allow one to study excitations with particle/antiparticle duality and non-abelian statistics. Most of the experimental setups with nanoscale circuits use semiconducting nanowires with strong spin-orbit interaction connected to superconductors, under a finite magnetic field [1]. Theoretical proposals have suggested autonomously inducing the spin-orbit coupling through a magnetic texture [2]. In this work, we demonstrate experimentally such a platform using a single wall carbon nanotube as a conductor, which naturally exhibit few conduction channels. It is stamped over a magnetically textured gate and coupled to two superconducting electrodes. We observe subgap states in the conductance of such device, and perform a detailed study of their magnetic field evolution that reveals a large synthetic spin-orbit energy. Furthermore, a robust zero energy state, the hallmark of devices hosting localized Majorana modes, emerges at zero magnetic field. Our findings could be used for advanced experiments, including microwave spectroscopy and braiding operations.
Reference

V. Mourik, K. Zuo, S. M. Frolov, S. R. Plissard, E. P. A. M. Bakkers, and L. P. Kouwenhoven, Science 336, 1003 (2012).

R. Egger, K. Flensberg, Phys. Rev. B 85, 235462 (2012).

Keywords: Majorana fermions, quantum dots, carbon nanotube, topological quantum computing, spin orbit coupling

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STRONG COUPLING BETWEEN AN ELECTRON IN A QUANTUM DOT CIRCUIT AND A PHOTON IN A CAVITY

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In this talk I will present results on a Cooper pair splitter embedded in a microwave cavity, in which the strong coupling regime has been reached. In this experiment, a new coupling scheme between the mesoscopic circuit and the microwave cavity has been engineer resulting in a lower sensitivity to charge noise. Recent progress on nanofabrication technique will also be presented.

Keywords: Cooper pair splitter, strong coupling, carbon nanotube

*Speaker

Heat Transport through nonuniform superconducting point contacts

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The heat transport through small nonuniform superconducting point contacts with helimagnetism is analized in function of the temperarure and barrier transparancy. The transport of the heat energy is derived using the nonequilibrium Green function.

Keywords: Heat transport, nonuniform superconductor

*Speaker

Toward mesoscopic quantum electrodynamics in the terahertz frequency range

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One of the most interesting aspects of science is the fundamental, coherent interaction of light and matter, down to the quantum level of countable photons and single electronic transitions. Such kind of investigations on atoms in resonant cavities constitute the field of cavity-Quantum ElectroDynamics[1] and were then extended to circuit-QED[2,3]: in the latter GHz-resonators, embedded into microwave circuits, are coupled to 0-dimensional systems, namely Josephson junctions. A further developement uses quantum dots as the matter part, aiming at the realisation of spin-qubits and at the investigation of fundamental physical phenomena[4,5]. In this project we want to couple to the internal transitions quantum dots realised in a carbon nanotube, whose energies fall in the THz frequency range, with a THz-split-ring resonator. The demonstration of strong coupling in such a system will close the frequency gap for this kind of investigations, while pushing forward condensed matter and quantum optical studies in the THz frequency range.

Haroche and Raimond, Exploring the quantum: Atoms, Cavities and Photons, Oxford Graduate Texts, 2006

Blais et al., Cavity quantum electrodynamics for superconducting electrical cir- cuits: An architecture for quantum computation, Phys. Rev. A 69, 062320 (2004)

Wallraff et al., Strong coupling of a single photon to a superconducting qubit using circuit quantum electrodynamics, Nature 431, 162 (2004)

Cottet et al., Cavity QED with hybrid nanocircuits: from atomic-like physics to condensed matter phenomena, arXiv:1709.00466

Frey et al., Dipole coupling of a double quantum dot to a microwave resonator, Phys. Rev. Lett. 108, 046807 (2012)

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Keywords: terahertz, quantum dot, carbon nanotube, strong coupling, QED