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Quantum tomography of electrical currents

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In quantum nanoelectronics, time-dependent electrical currents are built from single to few elementary excitations emitted with well-defined wavefunctions propagating coherently through the conductor. However, despite the experimental realizations of electronic sources generating quantized numbers of excitations, and despite the continuous development of the theoretical framework of time-dependent quantum electronics, extracting the electron and hole wavefunctions from any electrical current has so far been out of reach, both at the theoretical and experimental levels. In this work, by combining two-particle interferometry [1] with signal processing techniques, we demonstrate a protocol for the quantum tomography [2,3,4] of electrical currents able of extracting the generated electron and hole wavefunctions as well as their emission probabilities.
The interferometer is implemented in a 2D electron gas in the integer quantum Hall effect where charges propagate along 1D ballistic edge channels. First we demonstrate the protocol with sinusoidal currents which allow for simple comparison with theoretical predictions. Then we turn to periodic single electron Lorentzian pulses [5] and show that thermal effects lead to the generation of a statistical mixture between two single-electron wavefunctions.

By identifying specific single electron and hole wavefunctions, and determining their emission probabilities, our work opens the way to a precise and systematic characterization of quantum information carried by electrical currents.

E.Bocquillon et al. Science 339, 1054 (2013)

C.Grenier et al. New Journal of Physics 13, 093007 (2011)

T.Jullien et al. Nature 514, 603 (2014)

A.Marguerite et al. arXiv:1710.11181

J. Dubois et al., Nature 502, 659 (2013).

Keywords: Quantum electronics, quantum Hall effect, tomography, noise

*Speaker

A unified framework for time-dependent transport

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We present a unified theory for average current and noise in a quantum system subject to periodic or non-periodic time-dependent drives [1,2]. While requiring a weak current, it is non-perturbative with respect to strong Coulomb interactions or coupling to an electromagnetic environment. Some of the relations it provides have been experimentally tested in quantum circuits with normal and Josephson junctions [2,3]. Fully extending the Tien-Gordon theory for photo-assisted tunneling, our theory does not require initial thermalization nor inversion symmetry. Beyond a charge current, it applies as well to a spin current or a voltage drop across a phase-slip Josephson junction, as confirmed theoretically by F. Hekking's group [4].
A direct application of our theory is a determination of the carrier charge in the Fractional Quantum Hall Effect which is free from unknown parameters, as recently implemented by C. Glattli's group [5]. We also revisit the generation of minimal excitations in such non-linear systems. Then we propose to use the photo-drag current as a spectroscopic probe of the third cumulant of a non-gaussian source.

I. Safi, arxiv:1809.08290 ; arxiv :1401 :5950. B. Roussel P. Degiovanni & I. Safi, Phys. Rev. B **93**, 045102 (2016).

O. Parlavecchio *et al,*Phys. Rev. Lett. **114**, 126801 (2015)

C. Altimiras *et al.*, Phys. Rev. Lett. 112, 236803 (2014). S. Houle *et al*, arXiv:1706.09337. S. Jebari *et al*, Nature Electronics **1**, 223(2018).

A. Di Marco, V. F. Maisi, J. P. Pekola, and F. W. J. Hekking, Phys. Rev. B 88, 174507 (2013)

M. Kapfer *et al*, under consideration for Science (2018)

Keywords: Time, dependent Transport, Quantum circuits, Fractional Quantum Hall effect, Third cumulant detection, Minimal excitations

*Speaker

Crystallization of Levitons in a strongly interacting background

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We review recent theoretical results regarding Leviton excitations generated in fractional quantum Hall edge channels and carrying a charge multiple of the electronic one [1]. Despite involving several Laughlin quasiparticles these states leave a Poissonian signature in a Hanbury-Brown and Twiss partition noise measurement at low transparency [2]. Further peculiar features associated to these clean and robust emerging excitations can be detected through collisional experiments. In particular, the electron density outgoing from a quantum point contact is predicted to show a regular pattern of peaks and valleys, reminiscent of analogous self-organization recently observed for optical solitons in non-linear environments. This crystallization phenomenon is confirmed by additional side dips in the Hong-Ou-Mandel noise, a feature that can be observed in nowadays electron quantum optics experiments, where Levitons with different charges collide against each other at a quantum point contact [3]. We describe this phenomenology both in the framework of the photo-assisted noise formalism and in terms of a very interesting and transparent picture based on wave-packet overlap.

D. Ferraro et al., arXiv:1809.01927.

J. Rech et al., Phys. Rev. Lett. 118, 076801 (2017).

F. Ronetti et al., Phys. Rev. B 98, 075401 (2018).

Keywords: Levitons, Laughlin sequence, Hong, Ou, Mandel interferometer, time crystallization

*Speaker

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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 high impedance series
resonators, we first show the equality between Cooper pair tunneling rate and photon production
rate [1]. Using two resonators with different frequencies, we demonstrate photon pair production
, two-mode squeezing, and entanglement between the two modes leaking out of the resonators.
Then we demonstrate a blockade regime for which the presence of a single photon blocks the next
tunneling event and the creation of a second photon [3]. Finally, I will show that combining the two
techniques, we can stabilize a Fock state in one resonator.

Keywords: Microwaves, quantum optics, josephson junction, superconducting circuit

*Speaker

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Coupling of mechanical modes to two-level systems: topological energy transfer

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I will give a short overview of recent progress in the field of mechanical modes coupled to two level systems. I will then consider the case of single molecules coupled by Stark effect to mechanical oscillators and detected by optical spectroscopy. It has been shown that the system can be used to detect the displacement of mechanical oscillator and it is expected to reach the strong coupling limit [1,2]. The method is also promising to detect vectorial forces, exploiting the two quasi-degenerate fundamental flexural modes [3]. We recently found [4] that this system can be used to observe a topologically controlled energy transfer between the two quasi-degenerate modes [5]. This phenomenon relies on the presence of exceptional points in the spectrum of the coupled system formed by the driven two level system and the mechanical modes. It allows a topological control of the mechanical oscillations. Its observation in single-molecule spectroscopy experiments is expected for realistic physical parameters. [1] V. Puller, B. Lounis, and F. Pistolesi, Phys. Rev. Lett. **110**, 125501 (2013). [2] F. Pistolesi, Phys. Rev. A **97**, 063833 (2018).[3] L. Mercier de Lépinay et al., Nature Nanotech. **12**, 156 (2017). [4] C. Dutreix, R. Avriller, B. Lounis, and F. Pistolesi (unpublished). [5] H. Xu, D. Mason, L. Jiang, and J. Harris, Nature **537**, 80 (2016).

Keywords: Nano Electro Mechanical Systems, Opto Mechanical Systems

*Speaker

Phonon-number-sensitive electromechanics

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The position of micromechanical oscillators can be controlled and measured with a precision better than their quantum zero-point motion. But because of these quantum fluctuations, the energy of the oscillator cannot be controlled at the quantum scale through coupling to position. We demonstrate a new class of electromechanics experiments which uses the strong intrinsic non-linearity of a microwave superconducting qubit with a 4 GHz transition frequency to directly detect and control the energy of a micro-mechanical oscillator vibrating at 25 MHz. The qubit behaves as a vibrational energy detector and from its lineshape we extract the phonon number distribution of the oscillator. With a resolution of 7 quanta, we manipulate this distribution by driving number state sensitive sideband transitions and we create profoundly non-thermal states [1]. Driving the lower frequency sideband transition, we cool the oscillator and increase its ground state population up to 0.48±0.13, close to a factor of 8 above its value at thermal equilibrium. Preliminary results show that using a combination of sideband drives, we are able to prepare and detect number-squeezed states, which are non-classical, non-Gaussian states of motion [2].

J. J. Viennot, X. Ma and K. W. Lehnert, arXiv 1808.02673, accepted at Phys. Rev. Lett (2018)

J. J. Viennot et al., In preparation, unpublished

Keywords: Electromechanics, superconducting circuits, circuit quantum electrodynamics

*Speaker

Microwave spectroscopy of a weakly-pinned charge density wave in a Josephson-junction chain

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The proliferation of quantum phase slips in a Josephson-junction chain results in a Berezinskii-Kosterlitz-Thouless transition from a superconducting state characterized by well-defined phases to a Bose glass of localized charges. The transition takes place when the effective impedance of the chain is of the order of the resistance quantum. In a typical chain, the charge density is weakly pinned at this point. We find signatures of the pinning in the scattering amplitude of microwave photons reflected off a finite-length Josephson-junction chain. The evaluated frequency dependence of this reflection amplitude carries information regarding the dynamics of pinned charge density from the short-wavelength range described by the Giamarchi-Schulz scaling all the way up to the scales exceeding the Larkin pinning length. We compare our predictions with the results of a recent experiment.

Keywords: quantum phase slip, Josephson junction array, microwave spectroscopy, disorder

*Speaker

Highly coherent spin states in carbon nanotubes coupled to cavity photons

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Circuit quantum electrodynamics allows one to probe, manipulate and couple superconducting quantum bits using cavity photons at an exquisite level. Mesoscopic-QED inherits the c-QED toolbox and applies it to quantum dot circuits. In this talk, I will present a spin-qubit encoded in a carbon nanotube based double quantum dot with non-collinear ferromagnetic contact[1][2]. Using the c-QED spin-photon interface, we drove a single electronic spin and performed microwave spectroscopy of it. From this measurement we identied a decay rate which can be tuned to be as low as 250kHz. By performing time domain manipulations via pulses in the cavity eld, we demonstrate a Rabi decay time of about 2 μs. These coherence properties, which are attributed to the use of pristine carbon nanotubes stapled inside the cavity, should enable coherent spin-spin interaction via cavity photons and compare favorably to the ones recently demonstrated in Si-based circuit QED experiments[3].

A. Cottet, T. Kontos, Phys. Rev. Lett. 105, 160502 (2010)

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

X. Mi et al., Nature 555, 7698 (2018)

Keywords: Spin qubit, c, QED, carbon nanotubes

*Speaker

An Introduction to Machine Learning for physicists

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Machine learning techniques are getting increasingly popular. They can be used for a wide variety of tasks such as analyzing pictures (face recognition) or sound (voice recognition) or play games such as chess or go. Most of the concepts of machine learning are already well known to physicists although machine learning provides an interesting new point of view. In this introduction, I will discuss these basic concepts. I will also present some recent works where machine learning has been used to address some physics problems or vice-versa.

Keywords: machine learning, artificial intelligence, Christoph Mora

*Speaker

Machine Learning for Quantum Many-body Physics

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This talk will give an introduction and an overview of the rapidly growing field of machine learning used as a ressource to detect, descrive and solve quantum many-body systems in condensed matter physics.

Keywords: Machine learning, neural networks, phase transitions

*Speaker

Recurrent Neural Network for the Prediction of Quantum Trajectories from Raw Observations.

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Quantum mechanics provides us with an accurate set of rules to optimally predict the outcome of experiments, however it is also infamous for being abstract and highly counter intuitive. Neural networks are powerful tools to extract non-trivial correlation in vast datasets, they recently outperformed state-of-the-art techniques in language translation, medical diagnosis or image recognitions. It remains to be seen if they can be of aid in learning non-intuitive dynamics such as ones found in quantum systems without any prior. Here, we demonstrate that a recurrent neural network can be trained in real time to infer the quantum evolution of a superconducting qubit under non-trivial unitary evolution and continuous measurement from raw experimental observations only. These predictions are exploited to extract the system Hamiltonian, measurement operators and parameters such as quantum efficiency with a greater accuracy than usual calibration methods. Also, the quantum tomography of an unknown initial state is performed without prior calibration. This work shows that quantum mechanics can be inferred from observation based on deep learning methods and can be readily extended to larger quantum system in a model independent fashion to enhance quantum sensing or QCVV.

Keywords: Neural Networks

*Speaker

Gate tunable superconductivity and ballistic transport in Germanium two dimensional hole gas

Florian Vigneau * [1], Raisei Mizokuchi [1], Dante Colao Zanuz [1], Xuhai Huang [2], Susheng Tan [3], Romain Maurand [1], Sergey Frolov [2], Amir Sammak [4,5], Giordano Scappucci [4], Maksym Myronov [6], François Lefloch [1], Silvano De Franceschi [1]

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Hybrid superconductor-semiconductor structures attract increasing attention owing to a variety of potential applications in quantum computing devices. They can serve to the realization of topological superconducting systems, as well as gate-tunable superconducting quantum bits. Starting from nominally undoped SiGe/Ge/SiGe quantum-well heterostructures hosting high-mobility two-dimensional holes we fabricated quantum wires through a top-down approach. We demonstrate ballistic transport and reveal the anisotropy of the g factor [R Mizokuchi, *et al.* Nano letters, 2018].
Then we combine aluminum superconducting leads to the Ge quantum-well to realize prototypical planar hybrid devices, such as Josephson field-effect transistors (JoFETs) and superconducting quantum interference devices (SQUIDs). We observe gate-controlled supercurrent transport with Ge channels as long as one micrometer and measure the induced superconducting gap from tunnel spectroscopy measurements in superconducting point-contact devices. Our sample fabrication method is supported by transmission electron microscopy.

Keywords: Ballistic transport, holes, germanium, g, factor, Josephson Junction, Superconductivity, SQUID

*Speaker

Putting a spin on the Josephson Effect

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[2] Quantronics group (QUANTRONICS) – CNRS : URA2464, CEA-DRF-IRAMIS – Quantronics Group, Service de Physique de l'Etat Condensé, DRF/IRAMIS, CEA-Saclay, F-91191 Gif-sur-Yvette, France
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The Josephson supercurrent that flows through a weak link between two superconductors is mediated by fermionic quasiparticle states localized at the weak link: the Andreev bound states. To explore the role of the spin of these states, we have performed their microwave absorption spectroscopy in superconducting weak links with strong spin-orbit coupling: an InAs-Al (core-full shell) epitaxially-grown nanowire. The spectra present distinctive features that we interpret as arising from zero-field spin-split Andreev states. A simple analytical model, which takes into account the Rashba spin-orbit interaction in a multichannel nanowire, explains these features and their evolution with magnetic field. Our results show that the spin of quasiparticles can be a relevant degree of freedom in Josephson weak links.

Keywords: Supraconductivité mésoscopique, Spin, orbite, Nanowires

*Speaker
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Topological quantum chemistry and finding higher order Topological Insulators

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We propose an electronic band theory that highlights the link between topology and local chemical
bonding, and combines this with the conventional band theory of electrons. Topological Quantum
Chemistry is a description of the universal global properties of all possible band structures and materials, comprised of a graph theoretical description of momentum space and a dual group theoretical description in real space.

Keywords: quantum chemistry, higher order topological insulator

*Speaker

High frequency probing of the topological protection of Bismuth nanowire hinge states

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Bismuth has very recently been shown to belong to the family of Higher Order Topological Insulators [1], i.e. materials with insulating bulk and surfaces, but with metallic 1D "hinges" at the junction of its surfaces. We have previously revealed the ballistic nature of such hinge states in monocrystalline nanowires connected to superconducting contacts, via the measurement of the supercurrent-versus-phase relation [2,3]. I will present our recent measurement of the nanowire's linear response to an ac phase difference excitation. I will argue that the response's sharp dissipation peak when the superconducting phase difference is pi points to a topological protection of the Andreev levels carrying the supercurrent at the hinges [4].

Keywords: supraconductivite, topologie

*Speaker

Manipulating type-I and type-II Dirac polaritons in cavity-embedded honeycomb metasurfaces

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Pseudorelativistic Dirac quasiparticles have emerged in a plethora of artificial graphene systems that mimic the underlying honeycomb symmetry of graphene. However, it is notoriously difficult to manipulate their properties without modifying the lattice structure. Here we theoretically investigate polaritons supported by honeycomb metasurfaces and, despite the trivial nature of the resonant elements, we unveil rich Dirac physics stemming from a non-trivial winding in the light-matter interaction. The metasurfaces simultaneously exhibit two distinct species of massless Dirac polaritons, namely type-I and type-II. By modifying only the photonic environment via an enclosing cavity, one can manipulate the location of the type-II Dirac points, leading to qualitatively different polariton phases. This enables one to alter the fundamental properties of the emergent Dirac polaritons while preserving the lattice structure, a unique scenario which has no analog in real or artificial graphene systems. Exploiting the photonic environment will thus give rise to unexplored Dirac physics at the subwavelength scale.

Ref: C.-R. Mann, T.J. Sturges, G. Weick, W.L. Barnes, E. Mariani, Nat. Commun. **9**, 2194 (2018)

Keywords: metamaterials, artificial graphene, strong light, matter coupling, polaritons

*Speaker

Granular aluminum: A superconducting material for high impedance quantum circuits

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Superconducting quantum information processing machines are predominantly based on microwave circuits with relatively low characteristic impedance, of about 100 Ohm, and small anharmonicity, which can limit their coherence and logic gate fidelity. A promising alternative are circuits based on so-called superinductors, with characteristic impedances exceeding the resistance quantum R_Q = 6.4 kOhm. However, previous implementations of superinductors, consisting of mesoscopic Josephson junction arrays, can introduce unintended nonlinearity or parasitic resonant modes in the qubit vicinity, degrading its coherence. I will present a fluxonium qubit design using a granular aluminum (grAl) superinductor strip. Granular aluminum is a particularly attractive material because it self-assembles into an effective junction array with a remarkably high kinetic inductance [1] and low losses [2]. Moreover, its fabrication can be in-situ integrated with standard aluminum circuit processing. The measured Ramsey coherence time, up to 30 μs [3], illustrates the potential of grAl for applications ranging from protected qubit designs to quantum limited amplifiers and detectors.

Maleeva et al. Nature Comm. 9, 3889 (2018)

Grunhaupt et al. Phys. Rev. Lett. 121, 117001 (2018)

Grunhaupt, Spiecker, et al. arXiv:1809.10646 (2018)

Keywords: fluxonium qubit, granular Aluminum, cQED, Josephson junction, superconducting detectors

*Speaker

Probing the influence of many-body fluctuations on Cooper pair tunneling using circuit QED

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Because of the value of the hyperfine constant (_˜ 1/137) observing many body effects in light-matter interaction is challenging. Reaching this regime is now possible using the tools of circuit Quantum ElectroDynamics (cQED) [1,2].
In this work we investigate the interactions between the plasma modes propagating in arrays of more than 4000 SQUIDs (which simulate the light) and a superconducting quantum bit (the matter). The first effect of these modes is to broaden the energy level of the qubit [1,2]. More interestingly they can also induce strong phase fluctuations across the Josephson junction forming the qubit, which directly affects the Cooper pair tunneling. This effect is equivalent to a many-body Lamb shift. I will present our on-going experimental efforts aimed at observing this purely quantum many-body effect.

P. Forn-Díaz, et al. "Ultrastrong coupling of a single artificial atom to an electromagnetic continuum in the nonperturbative regime," Nature Physics, 13(1), 39–43 (2016).

J. Puertas Martínez, S.Léger, et al. "A tunable Josephson platform to explore many-body quantum optics in circuit-QED," arXiv:1802.00633.

Keywords: Qubit, High impedance, Quantum optics

*Speaker

Superconducting circuit protected by two-Cooper-pair tunneling

Clarke Smith * [1], Angela Kou [1], Xu Xiao [1], Uri Vool [1], Shyam Shankar [1], Michel Devoret [1]

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We present a protected qubit based on an effective circuit element that only allows pairs of Cooper pairs to tunnel. These dynamics give rise to a nearly degenerate ground state manifold indexed by the parity of tunneled Cooper pairs. We show that, when the circuit element is shunted by a large capacitor, this manifold can be used as a logical qubit that we expect to be insensitive to multiple relaxation and dephasing mechanisms. Like all protected qubits, ours suffers from difficulties in implementing readout and control; we conclude with a scheme for overcoming these difficulties using cascaded dispersive readout and indirect transitions.

Keywords: superconducting qubits, protected qubits

*Speaker

Realizing a Catch-Disperse-Release read-out of a qubit

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Fast read-out is an essential piece of measurement based error correction codes and is often limited by its reset time but the usual technique of driving a dispersively coupled resonator presents some limitations. To overcome those limits Sete and al. [1] proposed a catch, disperse and release scheme that we recently realized.
It uses a resonator with a tunable coupling to the transmission line. That resonator is coupled to the qubit in the dispersive coupling limit. First, we do brief unconditional coherent displacement of the resonator. Then the phase of the stored coherent state grows linearly in time at a rate depending on the state of the qubit. Finally, we release the resonator's state into the transmission line and measure the phase of the out-coming signal.

Our experiment implements that scheme by using a Josephson Parametric Converter as a tunable coupler between a low and a high Q factor resonator [2] to measure a transmon qubit in CPW geometry.

We demonstrate a state-of-the-art read-out with a fidelity of 98.5% in a total of 220 ns. The fidelity is limited by the 6us qubit's lifetime. We demonstrate the quantum non-demolition, reset, and Purcell protection granted by this scheme.

: Sete and al., PRL 110

: Flurin and al., PRL 114

Keywords: readout, qubit, oscillators, catch, disperse, release

*Speaker

Topological geo-physical waves

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The rise of topological states of matter stimulated the search for analogous properties in various platforms, from artificial quantum systems to classical metamaterials. Actually, the existence of several natural macroscopic waves, known long before the quantum Hall effect, that propagate in oceans and atmospheres, may be understood with similar topological tools, in particular with the first Chern number. I will present two examples of such waves: the equatorial Kelvin and Yanai waves, that only propagate eastward along the equator, and the atmospheric Lamb waves that are generated by violent events such as volcanic eruptions or nuclear explosions.

Keywords: Topology, boundary modes, waves

*Speaker

two-dimensional topological superconductivity in Pb/Co/Si(111)

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Majorana states are predicted to appear as edge states of topological superconductors, in a similar way as Dirac surface states appears at the edge of topological insulators. Spectroscopic signatures of Majorana bound states were claimed to be observed in one-dimensional (1D) InAs nanowires proximity-coupled to a bulk superconductor [1]. Then Nadj-Perge et al. [2] have realized a chain of Fe adatoms on a Pb(110) crystal that is supposed to induce locally a 1D topological p-wave superconductivity. Zero-energy bound states were observed at the extremity of some the Fe chain and interpreted as Majorana excitations [2]. Nevertheless this interpretation is challenged by close to zero-energy Shiba states [3]. We have recently decided to follow a different strategy using a two-dimensional superconducting system consisting in a monolayer of Pb atoms grown on Si(111) [4]. We have shown that the strong spin-orbit coupling of Rashba type present in the superconductivity of the Pb/Si(111) monolayer can be revealed through the filling of in-gap quasiparticle states by scattering from non-magnetic disorder at 300 mK [5]. Following Rashba and Gor'kov this shows that a mixed singlet-triplet superconductivity exists in our Pb monolayer [6]. Nano-magnetic disks made of CoSi alloy grown below the Pb/Si(111) monolayer were used to induce locally 2D topological superconductivity by combining a strong local Zeeman field with a mixed singlet-triplet 2D superconductor. We have observed that dispersive edge states appear in the superconducting gap at the boundary of the magnetic domains [7]. We have interpreted these spectroscopic features as signatures of a locally induced 2D topological superconductivity. Indeed, we expect to get propagative dispersive Majorana edge states around 2D topological domains since the edges have a 1D character. Furthermore, larger buried Co-Si disks present a different magnetic structure, enabling the spatial observation of a concentric pair of Majorana excitations. We explain these results through the existence of a vortex in the magnetic structure of the Co-Si islands. References 1. V. Mourik et al., "Signatures of Majorana Fermions in Hybrid Superconductor-Semiconductor Nanowire Devices" Science 346, 602 (2012). 2. S. Nadj-Perge et al., "Observation of Majorana fermions in ferromagnetic atomic chains on a superconductor" Science 336, 1003 (2014). 3. M. Ruby et al., "End States and Subgap Structure in Proximity-Coupled Chains of Magnetic Adatoms" PRL 115, 197204 (2015). 4. T. Zhang et al. "Superconductivity in one-atomic-layer metal films grown on Si(111) " Nature Phys. 444, 10 (2014). 5. C. Brun et al., "Remarkable effects of disorder on superconductivity of single atomic layers of lead on silicon" Nature Phys. 444,

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10 (2014). 6. E.I. Rashba and L.V. Gor'kov, "Superconducting 2D System with Lifted Spin Degeneracy: Mixed Singlet-Triplet State" PRL 444, 10 (2010). 7. G. C. Ménard et al., "Two-dimensional topological superconductivity in Pb/Co/Si(111)", Nature commun. 8, 2040 (2017) doi:10.1038/s41467-017-02192-x

Keywords: supraconductivité topologique 2D, transition topologique, paires de Majorana

Topological Phase Detection in Rashba Nanowires

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We study theoretically the detection of the topological phase transition occurring in Rashba nanowires with proximity-induced superconductivity using a quantum dot. The bulk states lowest in energy of such a nanowire have a spin polarization parallel or antiparallel to the applied magnetic field in the topological or trivial phase, respectively. We show that this property can be probed by the quantum dot created at the end of the nanowire by external gates. By tuning one of the two spin-split levels of the quantum dot to be in resonance with nanowire bulk states, one can detect the spin polarization of the lowest band via transport measurement. This allows one to determine the topological phase of the Rashba nanowire independently of the presence of Majorana bound states.

Keywords: Topological matter, Topological transition, Transport Measurement

*Speaker

Circuit Quantum Simulation of a Tomonaga-Luttinger Liquid with an Impurity

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The Tomonaga-Luttinger liquid (TLL) concept is believed to generically describe the strongly-correlated physics of one-dimensional systems at low temperatures. A hallmark signature in 1D conductors is the quantum phase transition between metallic and insulating states induced by a single impurity. However, this transition impedes experimental explorations of real-world TLLs. Furthermore, its theoretical treatment, explaining the universal energy rescaling of the conductance at low temperatures, has so far been achieved exactly only for specific interaction strengths. Quantum simulation can provide a powerful workaround.
Here, we implement the analogue of a TLL of adjustable electronic interactions comprising a single, fully tunable scattering impurity with a hybrid metal-semiconductor dissipative quantum circuit. I will show measurements revealing the renormalization group 'beta-function' for the conductance, that completely determines the TLL universal crossover to an insulating state upon cooling. Moreover, the characteristic scaling energy locating at a given temperature the position within this conductance renormalization flow is established over nine decades versus circuit parameters, and the out-of-equilibrium regime is explored. With the quantum simulator quality demonstrated from the precise parameter-free validation of existing and novel TLL predictions, quantum simulation is achieved in a strong sense, by elucidating interaction regimes which resist theoretical solutions.

Reference: A. Anthore *et al.*, Phys. Rev. X **8**, 031075 (2018)
Viewpoint in Physics: E. Dalla Torre, E. Sela, Physics **11**, 94 (2018)

Keywords: Liquides de Luttinger, Blocage de Coulomb dynamique, Simulation quantique, Transition de phase quantique, Transition métal isolant

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Reconstructing the underlying analytical structure of Feynman diagrams expansions

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Feynman diagrams are a central concept of modern quantum and statistical physics with applications ranging from collisions at very high energy to correlated electronic systems or phase transitions. They provide the different contributions to a systematic series expansion in power of a coupling constant U of the theory. Recent progress in quantum Monte-Carlo techniques have made possible the systematic numerical calculations of these series up to U^{15} or higher. However, these series often possess a finite convergence radius U_c so that even with many terms of the series, the result diverges for $U > U_c$ blocking access to the physical regimes of interest. We developed a technique that allows one to reconstruct the positions of the singularities that cause these divergence. This knowledge is used to construct a tailored conformal transformation that sends these singularities away from the point of interest. We apply this technique to the emblematic Anderson impurity model and show that one can access regimes well beyond the "convergence radius wall" in a robust and systematic fashion. We further describe a new expansion of the real time connected diagrammatic Monte-Carlo technique and a Bayesian inference technique that, combined, make these calculations possible. These results provide a route around a major bottleneck of perturbative approaches and may have deep implications in various fields of physics.

Keywords: Monte, Carlo, convergence radius, Kondo, out, of, equilibrium

*Speaker

Orbital graphene: topological properties of distorted flat bands

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In graphene, a honeycomb lattice of atomic states with pz symmetry leads to the well-known electronic spectrum with two inequivalent Dirac points connecting the valence and the conduction bands. The existence of zero energy states relating these two points depends on the nature of the edges, e.g. zig-zag, bearded or armchair.
Higher energy atomic states with different symmetries are not reachable in graphene but can be probed in artificial graphenes. The spectrum associated to these new orbitals is quite rich and exhibits new interesting features like flat bands and new edge states. The domain of existence of these edge states is complementary to those of pz symmetry and results from a duality between the new bands and the pz band. Their existence is related to topological properties of the bulk Hamiltonian and to a generalization of the Zak phase.

Under lattice distortion, the deformation of the flat bands gives rise to a new family of tilted Dirac cones, dispersionless along one direction. Their evolution under further distortion leads to introducing a new topological concept, the winding vector, a notion which generalizes the one of winding number [1].

All these novel features have been recently observed in a polariton lattice of semi-conducting micropillars [2].

Winding vector: how to annihilate two Dirac points with the same charge, G. Montambaux, L.K. Lim, J.N. Fuchs, F. Piéchon, arXiv:1804.00781

Tilted and type-III Dirac cones emerging from flat bands in photonic orbital graphene, M. Milićević, G. Montambaux, T. Ozawa, I. Sagnes, A. Lemaître, L. Le Gratiet, A. Harouri, J. Bloch, A. Amo, arXiv:1807.08650

Keywords: flat bands, edge states, Dirac cones, winding vector, polaritons

*Speaker

Imaging Dirac fermions flow through a circular Veselago lens

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With the recent progresses in building high mobility graphene samples, new electron optics devices have been envisioned, mostly based on the use of p-n interfaces. At p-n boundaries Dirac fermions behave as would photons encountering a negative index media, therefore experiencing a peculiar refraction known as Veselago lensing. However the way Dirac fermions flow through a Veselago lens remains largely unexplored experimentally. Here we present a way to create a movable and highly tunable circular Veselago lens in graphene, using the polarized tip of a scanning gate microscope.

By scanning the tip in the vicinity of a constriction while recording the device conductance, we obtain images related to the electron flow through this circular Veselago lens. In particular, we observe a high current density in the lens core and evidence two anti-focusing points along transport axis. Tight-binding simulations indicate that these anti-focusing points strongly depend on the pn junction smoothness. Our work paves the way towards a deep understanding of Dirac fermions optical elements, a prerequisite to engineer relativistic electron optics devices.

Keywords: Graphene, scanning probe, electron optics

*Speaker

Magnetotransport in a graphene gate-defined saddle point constriction

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Since its discovery a decade ago, graphene has opened the field of 2D materials and is still of great importance for fundamental and applied physics. In particular, its gapless linear energy dispersion gives access to the new physics of Dirac fermions. However, the absence of gap is also detrimental to the engineering of advanced nanostructures, by preventing the depletion of the electron gas underneath local gates. In graphene, electrostatic gating only creates p-n junctions, that are highly transparent due to Klein tunneling [1]. Nevertheless, in a previous study, some of us demonstrated the possibility to operate a gate-defined constriction in high mobility graphene as a Quantum Point Contact in the quantum Hall regime [2]. But the low-field physics of the constriction's saddle-point potential has not been investigated so far.

Here we present the magnetic field dependence of a gate-defined constriction in high mobility graphene heterostructures and show that specific properties of the constriction's saddle-point potential can be investigated [3]. At low magnetic field, transport is characterized by ballistic Fabry-Pérot resonances in the n-p-n cavity created by the top-gates and no quantization is observed. Upon increasing the magnetic field, Fabry-Pérot oscillations vanish and are replaced by Landau levels oscillations in the constricted region. Simulations confirm that these Landau levels are specific to a saddle-point potential. The Landau levels turn into quantum Hall plateaux at high magnetic field, where a Quantum Point Contact operation can be realized [2]. In the intermediate regime, snake states devellop around the pn interfaces, inducing characteristic resistance oscillations. Simulations reveal a regime where snake orbits propagate through the constriction.

Katsnelson et al., Nature (2006)

Zimmermann et al., Nature Communications 8, 14982 (2017)

Veyrat et al., arXiv:1806.10087

*Speaker

Keywords: Graphene, QPC, saddle potential, snake states

Manipulation and transport of charge carriers and excitons in van der Waals heterostructures based on transition metal dichalcogenides

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Due to their two-dimensional semiconducting nature, mono- and few layer transition metal dichalcogenides (TMDs) share many similarities in their optoelectronic properties with both the widely studied two-dimensional electron gases and III-V quantum wells. Among those properties are large transport tunability through electrostatic gating and strong light absorption through visible interband and mid-infrared intersubbband transitions [1-3]. In this tutorial talk, I will first give a quick overview of these main features of the TMDs. I will then follow with the description of a few original studies in these systems related to mesoscopic physics.
Indeed, recent progress in the nanofabrication of van der Waals heterostructures – the stacking of several two-dimensional materials layers of different nature – has enabled important breakthroughs in mesoscopic transport. For instance, encapsulation with boron nitride reduces disorder in monolayer TMD enough to observe quantum transport in gate-defined channels and constrictions [4]. Moreover, coupling different TMDs in heterobilayer stacks allows for ultrafast charge transfer between layers. When electron-hole pairs are generated with light, this transfer leads to carrier separation and the establishment of a long lived population of interlayer excitons – electron-hole pairs strongly bound through Coulomb interaction although they reside in different layers – stable even at room temperature. By patterning their potential landscape with gates, these neutral excitons can be manipulated [5] and transported along distances of a few micrometers [6]. These may open new opportunities to achieve coherent logic operations at room temperature if coupled to the valleytronics schemes original to these materials.

K.F. Mak and J. Shan. Photonics and optoelectronics of 2D semiconductor transition metal dichalcogenides. *Nature Photonics* volume 10, pages 216–226 (2016)

M. Massicotte, F. Vialla *et al.* Dissociation of 2D excitons in monolayer Wse2. *Nature Communications* 9, 1633 (2018)

P. Schmidt, F. Vialla *et al.* Nano-imaging of intersubband transitions in van der Waals quantum wells. *Nature Nanotechnology* (2018) doi:10.1038/s41565-018-0233-9

K. Wang *et al.* Electrical control of charged carriers and excitons in atomically thin materials.

*Speaker

Nature Nanotechnology volume 13, pages 128–132 (2018)

F. Vialla *et al.*, submitted

D. Unuchek *et al.* Room-temperature electrical control of exciton flux in a van der Waals heterostructure. *Nature* volume 560, pages 340–344 (2018)

Keywords: van der Waals heterostructure, transition metal dichalcogenide, exciton

Signatures of van Hove Singularities Probed by the Supercurrent in a Graphene-hBN Superlattice

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The band structure of graphene can be strongly modified if its lattice is aligned with the one of a boron nitride substrate. A moiré superlattice forms, which manifests itself by the appearance of new Dirac points, accompanied by van Hove singularities. In this work, we present supercurrent measurements in a Josephson junction made from such a graphene superlattice in the long and diffusive transport regime, where the critical current depends on the Thouless energy. We can then estimate the specific density of states of the graphene superlattice from the combined measurement of the critical current and the normal state resistance. The result matches with theoretical predictions and highlights the strong increase of the density of states at the van Hove singularities. By measuring the magnetic field dependence of the critical current, we find the presence of edge currents at these singularities. We explain it by the reduction of the Fermi velocity associated with the van Hove singularity, which suppresses the supercurrent in the bulk while the electrons at the edges remain less localized, resulting in an edge supercurrent. We attribute these different behaviors of the edges to defects or chemical doping. Ref: D.I. Indolese, R. Delagrange, P. Makk, J.R. Wallbank, K. Wanatabe, T. Taniguchi, and C. Schönenberger. Phys. Rev. Lett. 121, 137701 (2018).

Keywords: graphene superlattice, van Hove singularity, supercurrent

*Speaker

From confining superconductivity to quantized supercurrent

Rainer Kraft [1], Jens Mohrmann [1], Renjun Du [1], Pranauv Balaji Selvasundaram [2,3], Muhammad Irfan [4], Umut Nefta Kanilmaz [1], Fan Wu [1], Detlef Beckmann [1], Hilbert Von Löhneysen [1], Ralph Krupke [1,2], Anton Akhmerov [4], Igor Gornyi [1], Romain Danneau * [1]

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Graphene appears to be an ideal candidate for superconducting weak links, thanks to its low contact resistance, large mean free path and its two-dimensionality that provides device geometry flexibility. While graphene undergoes Klein tunneling making it inappropriate for charge carrier confinement, it is possible to create nanostructures based on band gap engineering in bilayer graphene (BLG). By using local displacement fields, we are able to confine charge carriers in 1D. Our superconducting leads allow measuring high ballistic supercurrent amplitudes and the study of the supercurrent confinement by probing its magnitude and the variations of the magneto-interference patterns while the constriction is formed. We demonstrate that it is possible to fully gate-control both amplitude and density profile of the supercurrent, making BLG a highly tunable superconducting weak link. Both analytical and numerical model support our findings. We also demonstrate that by adding a overall top gate, one better controls the 1D constriction and observes four fold degenerate quantized steps down to pinch-off. Finally, we demonstrate that, in these conditions, the extracted supercurrent is proportional to the number of conducting channels and therefore quantized.

Keywords: Proximity induced superconductivity, graphene, ballistic transport, quantized conductance

*Speaker

Tuning the topology of Andreev bound states in two and three-terminal Josephson junctions with a quantum dot.

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A Josephson junction made with a quantum dot, even in the simplest case where one dot level is relevant, is very peculiar due to the two-level state in the dot. This strongly quantum character has consequences on the topology of the Andreev bound states (ABS). This can already be probed in a two-terminal Josephson junction, by applying microwave drives with the same frequency but different phases to the two terminals. This chiral excitation results in a nonzero Josephson current even at zero applied flux. This phenomenon pertains to quantum pumping but can be studied well beyond the adiabatic (Thouless) regime, through a resonant regime where the microwave excites chiral transitions within the Andreev doublet. A relationship with Rice-Mele models appears in the limit of large gap where the junction state can be mapped on a bipartite linear chain model, each site of the chain being indexed by the number of pairs exchanged within the junction.
Three-terminal junctions (trijunctions) bridged by a dot are even more interesting : the equivalent " lattice " in the pair number space has the topology of a honeycomb lattice, and the ABS disperse in phase as the electronic states of graphene. All parameters of this effective lattice can be tuned, including a gap at points K, K'. Driving this trijunction with microwave in the adiabatic regime can be used to probe the topology of the ABS and fully map the Berry curvature as a function of the two junction phases. Moreover, driving the trijunction with a chiral microwave can create a topological state by closing and reopening (with band crossing) one of the ABS gaps. The resulting state is shown to be equivalent to that obtained by Haldane in 1988, and provides an easy realisation of this model. This picture should be complemented by the role of the quasiparticle continuum, which does only quantitatively modify the low-energy properties where the Berry curvature is relevant. Furthermore, weak interactions in the junction trigger quantum effects that can simulate edges in the equivalent "graphene" lattice, or properties like the Quantum Hall Effect.

Nonadiabatic Josephson current pumping by chiral microwave irradiation
B. Venitucci, D. Feinberg, R. Mélin, and B. Douçot, Phys. Rev. B 97, 195423 (2018).

Berry curvature tomography and realisation of topological Haldane model in driven three-terminal Josephson junctions
L. Peralta Gavensky, G. Usaj, C. Balseiro, D. Feinberg, Phys. Rev. B (Rapid. Comm.) 97, 220505 (2018)

*Speaker

Keywords: Jonctions Josephson, topologie, irradiation microonde, pompage quantique

Absence of dissipative quantum phase transition in Josephson junctions

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35 years ago, Schmid predicted that any Josephson junction connected to a resistor R has a superconducting to insulating quantum phase transition at R=4e^2/h6.5 kΩ. This publication is cited 350 times and, apparently, not questioned. We will first show that the predicted insulating phase is at odds with naive continuity arguments in simple known limits. Then, we will show the results of careful experimental tests which refute the insulating state, in agreement with the naive expectations.

Keywords: quantum phase transition, superconductor insulator transition, Josephson junction

*Speaker

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- Vigneau Florian
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- Vinel Vincent
- Waintal Xavier
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- Winkelmann Clemens
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Split-gate devices in silicon CMOS: tunable coupling and RF-reflectometry

Anthony Amisse *† [1], Heorhii Bohuslavsky [1], Rami Ezzouch [1], Agostino Aprà [1], Alessandro Crippa [1], Romain Maurand [1], Matias Urdampilleta [2], Tristan Meunier [2], Christopher Bauerle [3], Benoit Bertrand [4], Louis Hutin‡ [5], Maud Vinet [5], Silvano De Franceschi [1], Marc Sanquer [6], Xavier Jehl§ [1]

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Since the proposal of D.Loss and D. P. DiVincenzo in 1997 [1], semiconductor-based quantum dots have been widely studied as promising platform for Quantum computing. In Grenoble, the Quantum Silicon Group [2] is pursuing the development of silicon-based spin qubits relying on industrial-scale CMOS technology. To this aim, we leverage the expertise in microelectronics at Leti and the expertise in cryogenic transport and high-frequency measurements at the INAC and Neel institutes. Recently, we reported the first silicon spin qubit issued from a 300-mm CMOS fab line [3].

Our experiments are performed on double-gate nanowire transistors with a split-gate geometry [4].The poster is organized in two parts : the first one is dedicated to the tunable coupling between two quantum dots in a silicon nanowire thanks to a backgate voltage while the second part presents new results on gate radiofrequency (RF) reflectometry for the readout of the quantum dot charge and spin states [5]. [1] : Loss, D. et al. Quantum computation with quantum dots.

PRA 57, 120, doi: 10.1103/PhysRevA.57.120 (1998)

: https://www.quantumsilicon-grenoble.eu/

: Maurand, R. et al. A CMOS silicon spin qubit.
Nat. Commun. 7, 13575 doi: 10.1038/ncomms13575 (2016)

: Roche, B. et al. A two-atom electron pump.
Nat. Commun. 4, 2544 doi: 10.1038/ncomms2544 (2013)

: Gonzalez-Zalba, M.F. et al. Probing the limits of gate-based charge sensing.
Nat. Commun. 6, 6084 doi: 10.1038/ncomms7084 (2015)

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Keywords: Quantum dots, CMOS, Qbit, Reflectometry, Coupling

On-demand anti-bunched microwave photons from inelastic Cooper-pair tunneling

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Cooper-pair tunneling through a Josepshon junction embedded in a dissipationless circuit is elastic: The dc voltage across the junction has to be zero in order for Cooper pairs to tunnel through the junction. 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 leaving the junction through an open transmission line.

Without special care, these tunneling events are almost independent, leading to Poissonian or bunched statistics of the emitted photons. However, by designing particular high-impedance electromagnetic environments, the photon statistics can become antibunched.
We have designed such a high-impedance invironment by adding a RC circuit in series with the junction. Its high charging energy prevents two Cooper pairs from tunneling in close succession and, therefore, two photons from being emitted at the same time, leading to antibunched photons with a second-order correlation function $g^{(2)}(0) \approx 0.43$.$Inaddition, wehaveusedaSQUIDinsteadofasimp$
$bunchedphotonsondemanduptorates > 150MHz.Wealsoshowhowphotonstatisticsdependsonvoltageandfluxbi$

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

*Speaker

Proximity-induced superconductivity at nonhelical topological insulator interfaces

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We study how nonhelical spin textures at the boundary between a topological insulator (TI) and a superconductor (SC) affect the proximity-induced superconductivity of the TI interface state. We consider TIs coupled to both spin-singlet and spin-triplet SCs, and show that for the spin-triplet parent SCs, the resulting order parameter induced onto the interface state sensitively depends on the symmetries which are broken at the TI-SC boundary. For chiral spin-triplet parent SCs, we find that nodal proximity-induced superconductivity emerges when there is broken twofold rotational symmetry which forces the spins of the nonhelical topological states to tilt away from the interface plane. We furthermore show that the Andreev conductance of lateral heterostructures joining TI-vacuum and TI-SC interfaces yields experimental signatures of the reduced symmetries of the interface states.

Keywords: Topological Insulator, Superconductivity

*Speaker

Wide-band amplification and squeezing with a dc biased SIS junction parametrically pumped

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Although dc-biased SIS junction are routinely used as quantum-limited microwave mixers notably in radio-astronomy, their operation as linear voltage amplifiers has received very few theoretical investigation. Here we present an input-output analysis of the non-linear response of a dc-biased SIS tunnel junction to an electromagnetic signal in the presence of an additionnal pump tone. We show that the ac tone gives rise to a strong parametric pumping of the SIS admittance thus yielding to both phase sensitive/preserving amplification and to single/two-mode squeezing in degenerate/non-degenrate case. Both gain and two-mode squeezing bandwidths obtained in the non-degenerate case are naturally large in the few hundred MHz to GHz range. Morover, the device can be fine tuned in-situ with the help of the dc-bias and ac pump tone to achieved optimized narrower band opreation.

Keywords: SIS junction microwave detection, parametric amplifier

*Speaker

How fast does a voltage pulse travel through a quantum conductor ?

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Recent experiments provide direct information on the propagation of the excitations generated by a voltage pulse in two-dimensional systems. These systems are foreseen as a building bloc for implementing flying quantum bits. In this presentation we will show how one can construct these collective excitations from the microscopic model of the underlying electrons. We provide a new method that starts from the description of the sample (position of the gates, dopants, etc) and systematically builds the plasmons both in the 1D limit (Luttinger liquid) as well as in the quasi 1D limit. We report a quantitative agreement without adjustable parameter.

Keywords: self, consistency

*Speaker

Microwave photons emitted by fractional charges

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The characterization of elementary excitations in strongly correlated systems is still an active research field [1]. We introduce a new way to probe them in the fractional quantum Hall effect of a two dimensional electron gas. In this regime, transport occurs through anyonic quasiparticles with exotic properties such as their statistics which differ from fermions or bosons. To investigate this system, we measure microwave photons emitted by these quasiparticles [2,3] at filling factors 4/3 and 2/3. This measurement gives a direct access to their fractional charge e*.

Shifting by a DC voltage V the potential of one input of a quantum point contact enables the tunneling of charged quasiparticles. Then in an Ohmic environment, microwave photons at frequency f are emitted only when the incoming particles energy e*V is above photons energy hf. These photons are detected as high frequency noise [4,5] which appears at a voltage threshold inversely proportional to the charge.
The direct measurement method demonstrated here can be applied to any charged excitation in strongly interacting quantum systems.

M. Kapfer, et al. arXiv:1806.03117 (2018)

M. Carrega, et al. J. Phys.: Conf. Ser. 568 052005 (2014)

B. Roussel, et al. Phys. Rev. B 93, 045102 (2016)

A. Zazunov, et al. Phys. Rev. Lett. 99, 066601 (2007)

E. Zakka-Bajjani, et al. Phys. Rev. Lett. 99, 236803 (2007)

Keywords: Fractional quantum Hall effect, strongly correlated systems, Fractional charges, High frequency noise

*Speaker

Superconducting Silicon Resonators

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Despite being one of the most studied materials, the BCS superconductivity at ambient pressure of silicon was long ignored due to the extreme doping concentration required to trigger superconductivity, more than three times the boron solubility limit in silicon [1]. This concentration, impossible to reach using conventional micro-electronic techniques, was obtained by the 'Epla' group at C2N using Gas Immersion Laser Doping (GILD), an out of equilibrium technique achieving epitaxial Si:B thin films with concentrations as high as 11 at.% (6x10ˆ21cm-3).
The superconducting critical temperature Tc of the thin Si:B films only depends on the boron dose, increasing above a threshold value up to a maximum of 0.7 K [2]. The doping is 'box-like', homogeneous over the 10 to 300 nm thick layers, and spatially well-defined in the doped 2x2 mm^2 surface, with a sharp interface with the substrate, and without dopant aggregates [3].

The doping-tunable Tc and the mature silicon technology are coupled in superconducting silicon, allowing the conception of a large range of scalable quantum nanodevices, made of superconductors, metals and semiconductors coupled through extremely clean, transparent epitaxially grown interfaces.

We have thus realised the first silicon superconducting devices: SNS Josephson junctions where long-range proximity effect has been demonstrated [4], and superconducting quantum interference devices (dc-SQUID) [5].

In parallel to the study of the DC properties, we have started the investigation of the high frequency properties of Si:B, through the measurement of coplanar wavelength resonators coupled to a transmission line. We have explored the temperature dependence of the quality factor and resonant frequency, finding a good agreement with Mattis-Bardeen theory. The investigation of the power dependence has provided a measure of the non-linearity in the system. Finally, the multiple GHz resonant modes have shown an important kinetic inductance, expected from the Si:B high resistance and low Tc, which may lead to the development of silicon Kinetic Inductance Detectors.

*Speaker

References

E. Bustarret et al., *Superconductivity in doped cubic silicon*, Nature 444, 465 (2006).

A. Grockowiak et al., *Thickness dependence of the superconducting critical temperature in heavily doped Si:B epilayers*, Phys. Rev. B 88, 064508 (2013).

K. Hoummada et al., *Absence of boron aggregates in superconducting silicon confirmed by atom probe tomography*, Appl. Phys. Lett. 101, 182602 (2012).

F. Chiodi, et al., *Proximity induced superconductivity in all-silicon superconductor-normal metal junctions*, Phys. Rev. B 96, 024503 (2017)

J. E. Duvauchelle, et al., *Silicon Superconducting Quantum Interference Device*, Appl. Phys. Lett. 107, 072601 (2015)
Acknowledgments : D. Bouville, G. Hallais, T. Klein, C. Marrache

Keywords: silicon, resonators, Mattis Bardeen, Kinetic inductance, KID

Confinement and correlations at the LAO/STO (111) interface

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The LAO/STO interface has been known since 2004 to host a 2-dimensional electron gas (2DEG). In this work we use the Poisson Schrodinger model to investigate the properties of the (111) interface of the LAO/STO system which presents several difference with the (001) interface. We wish to model the effect of the correlations and of doping on such systems

Keywords: Oxides, 2DEG, electric gating

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Grid states for quantum error correction in superconducting circuits

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Any quantum system, however carefully designed or isolated, is bound to interact with an ensemble of degrees of freedom not controlled by the experimenter. This phenomenon, known as decoherence, leads to noise on the system which destroys the fragile states needed for performing quantum computation. To circumvent this issue, one can encode an elementary bit of quantum information in a higher dimensional system to correct for errors induced by decoherence. In 2001, Gottesman Kitaev and Preskill (GKP) proposed a hardware-efficient encoding based on grid states of a harmonic oscillator, which are coherent superpositions of squeezed states (Physical Review A, 64(1), 012310). Interestingly, this encoding was predicted to be robust against any type of physical noise. In this talk, I will present recent theoretical and experimental progress toward the creation and stabilization of GKP grid states in a superconducting circuit.

Keywords: error correction, quantum computing, bosonic codes

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Superconductivity in ultra-thin SOI by Pulsed Laser Induced Epitaxy

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We have demonstrated superconductivity in ultra-thin 23 and 33 nm SOI (Silicon On Insulator) substrates, currently used for FD-SOI (Fully-Depleted SOI) CMOS, as a first step towards the implementation of a silicon-based, scalable, superconducting electronics. We achieved the ultra-doping required to induce superconductivity in silicon (_˜ 1 at.%) by laser annealing and activation of high implanted doses of boron (_˜10ˆ16 cm-2). The technique used, Pulsed Laser Induced Epitaxy (PLIE), consists in locally melting the Si, driving a liquid-phase epitaxy of a Si:B layer over the underneath Si. Thanks to PLIE sharp box-like profile, we were able to control the annealing depth nanometer by nanometer, over a surface of 2x2 mm^2, a control which is crucial as there can be no crystalline epitaxy over the amorphous silica box. We have found that the structural properties of very thin, ultra-doped (10 at.%) layers are strongly affected by the laser annealing, creating a superconducting, expanded phase not yet fully understood.

Keywords: superconducting SOI, laser annealing

*Speaker

Coulomb enforced preservation of electronic coherence across a metallic island

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Coulomb interactions usually result in electronic decoherence. In the scattering approach to quantum transport, such decoherence is taken into account by introducing along the path an artificial voltage probe physically represented as "a metallic contact with a floating potential" [1]. However, it was recently predicted that the vanishing fluctuations of the metallic island's charge imposed by Coulomb interactions results in correlations between the connected electronic channels. A first manifestation is the heat Coulomb blockade of one ballistic channel [2] that was recently observed [3]. Most strikingly, if a single channel is connected to the metallic island, E. Sukhorukov and his team predicted that the injection of an electron into the island results in the emission of an indiscernible electron in the exact same quantum state [4]. In this poster, we present first experimental results establishing this prediction from the preserved quantum coherence revealed by an electronic Mach-Zehnder interferometer with one arm interrupted by a floating metallic island.

Förster, H., Samuelsson, P., Pilgram, S., Büttiker, M. Voltage and dephasing probes in mesoscopic conductors: A study of full-counting statistics. *Physical Review B* **75**, 035340 (2007).

Slobodeniuk, A. O., Levkivskyi, I. P., & Sukhorukov, E. V. Equilibration of quantum Hall edge states by an Ohmic contact. *Physical Review B* **88**, 165307 (2013).

Sivre, E., Anthore, A., Parmentier, F. D., Cavanna, A., Gennser, U., Ouerghi, A., Jin, Y., Pierre, F. Heat Coulomb blockade of one ballistic channel. *Nature Physics* **14**, 145 (2018).

Idrisov, E. G., Levkivskyi, I. P., & Sukhorukov, E. V. Dephasing in a Mach-Zehnder Interferometer by an Ohmic Contact. *Physical Review Letters* **121**, 026802 (2018).

Keywords: Electronic coherence, voltage probe, Mach Zehnder interferometer, quantum Hall effect

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Single-molecule non-reciprocal topological actuation of electromechanical modes

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Single-molecule spectroscopy has been proposed to detect the displacements of a single flexural mode of a carbon-nanotube cantilever [1,2]. Here we investigate the multimode dynamics of such a light electromechanical resonator, which is crucial for vectorial force microscopy [3]. We find that varying the intensity and frequency of the laser beam focusing on the single molecule over an adiabatic cycle enables to transfer energy from one flexural mode to another. We also show that this phenomenon is topological and non-reciprocal, and relies on the presence of an exceptional point in the electromechanical spectrum, as generally met in non-Hermitian systems [4]. Single-molecule spectroscopy could then be exploited to improve the multimode control of the nanomechanical oscillators.

V. Puller, B. Lounis, and F. Pistolesi, Phys. Rev. Lett. **110**, 125501 (2013).

F. Pistolesi, Phys. Rev. A **97**, 063833 (2018).

L. Mercier de Lépinay et al., Nature Nanotech. **12**, 156 (2017).

H. Xu, D. Mason, L. Jiang, and J. Harris, Nature **537**, 80 (2016).

Keywords: Single molecule spectroscopy, Carbone nanotube, Energy transfer, Exceptional point, Non reciprocity

*Speaker

Berry's phase atomic interferometers in graphene

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As a geometrical phase picked up by a quantum mechanical wave function over an adiabatic cycle, the Berry's phase in solids is usually experienced through the electron dynamics in response to electromagnetic fields [1]. In graphene, a high magnetic field was used to uncover an unconventional quantum Hall effect, which results from the Berry's phase acquired over cyclotron orbits enclosing a Dirac point [2,3]. Here, we present a new scanning tunneling microscopy approach to measure the graphene Berry's phase without breaking time-reversal symmetry. We report edge dislocations in the standing-wave interference pattern surrounding a chemisorbed hydrogen adatom. We show that such dislocations appear as phase singularities in the electronic interferences, and their topological charges are direct measurements of the Berry's phase. This establishes atomic impurities in solids as useful interferometers to study the topology of relativistic and gapped phases in scanning tunneling microscopy experiments.

D. Xiao et al., Rev. Mod. Phys. 82, 1959 (2010)

K. S. Novoselov et al., Nature 438, 197 (2005)

Y. Zhang et al., Nature 438, 201 (2005)

Keywords: Graphene, H adatom, Scanning Tunnelling Microscopy, Wavefront dislocation, Berry's phase

*Speaker

Thermopower signature of the Kondo effect in a quantum dot junction

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Quantum dots are an attractive model system for basic studies and applications in thermoelectricity, owing to their tunable electronic transmission and electron-hole asymmetry [1]. Further, as electronic devices' dimensions shrink towards the nano-scale, quantum effects associated with electron interactions [2] and correlation [3] gain increasing importance.
Here, we report on combined transport and thermopower measurements of a single quantum dot junction, at very low temperatures and in a regime where Kondo-correlations, due to the spin degeneracy of the odd charge states qQD of the quantum dot, dominate the electron transport processes. While in the absence of Kondo correlations, thermoelectric signals are generically periodic in qQD with period e, we observe here a 2e-periodic thermoelectric response. Furthermore, we experimentally verify a sign change of the thermopower signal in the Kondo regime as the temperature is increased, which is in good agreement with theoretical predictions for a Kondo-correlated quantum dot junction [4].

Keywords: Thermoelectricity, quantum transport, single quantum dot devices, Kondo effect

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Theory of plasmonic 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 modify the decay rates.

We present a theoretical framework to obtain the full 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 kagome lattices which present appealing topological features such as Dirac-like plasmons [1,2] and nondispersive plasmonic bands. Importantly, our model gives also access to the frequency shifts of the collective modes induced by the environments to which they are coupled. We finally discuss the experimental observability of such plasmonic modes.

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: Collective plasmons, Lifetime, honeycomb, Lieb

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A Classical Mechanism for Branching in the Scanning Gate Response of Two-Dimensional Electron Gases with Smooth Disorder

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Over the last two decades, developments in the field of scanning gate microscopy (SGM) have allowed for the detailed investigation of the microscopic properties of two-dimensional electron gasses by measuring the change in electrical conductance of a semiconductor heterostructure when a charged atomic force microscope is placed within its proximity. One of the most striking features of these SGM experiments is that in 2DEG systems with smooth disorder, they often yield a pattern of observed electron flow which is not uniform through space, as one might naively assume, but is rather organized into thin, collimated structures, typically referred to as "branches," despite the fact that the electrons propagate ballistically with a Fermi energy which is often significantly higher than the amplitude of this disorder potential. However, this branching phenomenon is not limited to 2DEG systems, and similar behaviour has in fact been observed in a variety of other physical phenomenon, ranging from the propagation of ocean waves and the focusing of tsunamis to microwave transport experiments and electron flow in Dirac solids. In the case of disordered 2DEG systems, previous work has identified local features of the disorder potential as being responsible for forming branches, which form due to localized dips or bumps in the disorder potential. In our present work, to be posted to the arXiv in the near future, we propose a specific physical mechanism of branch formation in 2DEG systems with smooth disorder, based upon the scattering of classical electron trajectories from localized features of the disorder potential. We indeed find that such a classical explanation is sufficient to elucidate the key features of branch formation.

Keywords: disorder, branching, 2DEG, electron gas, scanning gate microscopy, electron flow, transport

*Speaker

Does a Single Eigenstate Encode the Critical Behaviour of a Hamiltonian?

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The eigenstate thermalization hypothesis (ETH) has recently been the subject of a large body of experimental and theoretical work. ETH can explain how an isolated, quantum many-body system in an initial pure state can come to thermal equilibrium in finite time, and is thus fundamental to understanding the validity of conventional quantum statistical mechanics. One of the most striking conculsions of ETH is that within one individual energy eigenstate of a non-integrable quantum system, the reduced density matrix (RDM) of a sufficiently small subsystem will resemble that of a thermal one. The heuristic interpretation of this statement is that even in a pure energy eigenstate, the full system acts as a thermal reservoir for its small subsystems, thermalizing them through the quantum entanglement between the subsystem and the larger thermal reservoir. Here we will focus on what the information contained in one eigenstate reveals about the behaviour of a quantum, non-integrable system with a second-order phase transition at finite temperature. Previous work has suggested that ETH should also be expected to hold in such systems, and in a paper which will be posted to the arXiv soon, we will argue that if such a system with a finite-temperature phase transition satisfies ETH, then in principle, there should exist individual energy eigenstates of this system that can diagnose the existence of this phase transition, and which also contain quantitative information about its critical behaviour, without any knowledge of the original Hamiltonian itself.

Keywords: critical behaviour, finite, temperature phase transition, quantum thermalization, statistical mechanics, quantum chaos, symmetry breaking

*Speaker

Majorana flat band at the edge of magnetic skyrmions

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Magnetic skyrmions are topological spin textures currently at the forefront of research in spintronics because of their fundamental properties as well as their possible applications for memory devices [1]. From another perspective, the question of the interplay of magnetic textures and superconductivity has emerge as an attempt to engineer topological superconductivity. In that context, previous work has shown that magnetic skyrmions can host a Majorana zero mode (MZM) in their core when proximitized by a conventional s-wave superconductor. In constrast, we find a highly degenerate flat band of Majorana zero modes on the edge of the skyrmion that is robust to local perturbations be they electronic or geometric. We show that these states are similar to MZMs appearing at the end of Rashba wires. In addition, the number of MZMs in the flat band surprisingly grows linearly with the perimeter of the edge of the texture, irrespective of its precise shape. In turn, this implies that the MZM are localized on the nanometer scale which potentially allows for their individual adressing. We finally argue that the system considered here naturally implements a Majorana island which is suitable for the experimental realization of both non-local electron teleportation [3] and for the topological Kondo effect [5, 6].

N. Nagaosa & Y. Tokura, Topological properties and dynamics of magnetic skyrmions, *Nat. Nanotech.* **8**, 899-911 (2013).

L. Fu, Electron teleportation via Majorana bound states in a mesoscopic superconductor, *Phys. Rev. Lett.* **104**, 056402 (2010).

B. Béri & N. R. Cooper, Topological Kondo effect with Majorana fermions, *Phys. Rev. Lett.* **109**, 156803 (2012).

A. Altland & R. Egger, Multiterminal Coulomb-Majorana junction, *Phys. Rev. Lett.* **110**, 196401 (2013).

Keywords: Fermion de Majorana, skyrmion magnétique, supraconductivité, topologie

*Speaker

A mesoscopic spectrometer based on the Josephson effect

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The Josephson effect [1] allows converting a DC voltage to microwave oscillations at frequencies up to the terahertz range. The proportionality constant between voltage and frequency is the inverse of the magnetic flux quantum, $1/\Phi0 = 483.6$ MHz/μV. Absorption of the emitted microwaves can be directly measured in the current-voltage characteristic of the Josephson junction as a current peak.
Soon after the discovery of the Josephson effect, Silver and Zimmerman implemented an absorption spectrometer [2] and measured the nuclear magnetic resonance of Co 59 at 218 MHz using niobium point-contacts. Recently, the Quantronics group realized a spectrometer based on a Josephson junction [3] to probe Andreev Bound States in a superconducting atomic contact. Their device worked successfully but suffered two main drawbacks: a non-uniform coupling over the frequency range of interest and the presence of several spurious resonance peaks due to the electromagnetic environment of the junction. The spectrometer design presented here seeks to eliminate these issues.

Using a symmetrical SQUID biased at half a flux quantum allows significantly decoupling the spectrometer from environmental modes. In addition, a careful design of the biasing circuit reduces the number of remaining modes and damps them.

Coupling to the system of interest is made via a mutual inductance to the loop of the SQUID instead of through a capacitor. This guarantees uniform phase excitation across the inductance.

Spectra of four test systems are measured over a wide frequency range: an LC resonator mode at 150 GHz, the excitation of quasiparticles in a superconductor above 90 GHz, the plasma frequency of a Josephson junction at 15 GHz and the plasma frequency of a RF-SQUID at 80 GHz.

The mesoscopic spectrometer has a linewidth of 2 MHz, a bandwidth of 180 GHz and a noise equivalent power of 10ˆ–19 W/$\sqrt{}$Hz. We will use it to probe weak links based on InAs nanowires and on the topological insulator HgTe, in which the ABS spectrum is considerably modified by spin-orbit coupling. Another exciting direction is measuring unavoided energy crossings in topological superconducting quantum circuits.

References

Brian David Josephson. Possible new effects in superconductive tunnelling. Physics letters, 1(7):251-253, 1962.

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A. H. Silver and J. E. Zimmerman. Multiple quantum resonance spectroscopy through weakly connected superconductors. Applied Physics Letters, 10(5):142-145, March 1967.

L. Bretheau, Ç Ö Girit, H. Pothier, D. Esteve, and C. Urbina. Exciting Andreev pairs in a superconducting atomic contact. Nature, 499(7458):312-315, July 2013.

Keywords: Mesoscopic superconductivity, Josephson junction, Quantum circuits

Calorimetric Detection of Single Tunneling Electrons

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When inserting a single quantum dot (which can be a molecule or a nanoparticle) between two superconducting contacts, the resulting device can act as an on-demand single electron injector or turnstile. Moreover, in appropriate conditions of tunnel couplings, gate drive or magnetic field, the electron tunnelling can be made monochromatic and/or spin polarized. The goal of this PhD project is to couple such a single-electron source to an on-chip superconducting bolometer and to perform time-resolved detection of the heat released by individually injected electrons. This work will thereby pave the way for novel experiments about energy relaxation in the quantum regime, the energy release associated to elementary qubit operations, and, more generally, quantum thermodynamics in the time-domain.

Keywords: thermometry, NIS, rf

*Speaker

Orbital magnetism in ensembles of gold nanoparticles

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The last two decades have witnessed various experiments reporting very unusual magnetic properties of en-
sembles of gold nanoparticles surrounded by organic ligands, including ferromagnetic, paramagnetic, or (large)
diamagnetic responses. These behaviors are at odds with the small diamagnetic response of macroscopic gold
samples. Here we theoretically investigate the possibility that the observed unusual magnetism in capped gold
nanoparticles is of orbital origin. Employing semiclassical techniques, we calculate the orbital component to
the zero-field susceptibility of individual as well as ensembles of metallic nanoparticles. While the result for the
orbital response of individual nanoparticles can exceed by orders of magnitude the bulk Landau susceptibility in
absolute value, and can be either diamagnetic or paramagnetic depending on nanoparticle size, we show that the
magnetic susceptibility of a noninteracting ensemble of nanoparticles with a smooth size distribution is always
paramagnetic at low magnetic fields. In particular, we predict that the zero-field susceptibility follows a Curie-
type law for small nanoparticle sizes and/or low temperatures. The calculated field-dependent magnetization of
an ensemble of diluted nanoparticles is shown to be in good agreement with existing experiments that yielded
a large paramagnetic response. The width of the size distribution of the nanoparticles is identified as a key
element for the quantitative determination of the orbital response.[1] [1] *Orbital magnetism in ensembles of gold nanoparticles.* M. Gómez Viloria, G. Weick, D. Weinmann, R.A. Jalabert; August 2018, arXiv:1808.00815

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Keywords: Orbital magnetism, Semiclassical, Au nanoparticles

Entanglement clusters through the Many-Body Localization phase transition

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We study numerically the formation of entanglement clusters across the many-body localization phase transition.
We observe a crossover from strong many-body entanglement in the ergodic phase to weak local correlations in the localized phase, with contiguous clusters throughout the phase diagram.
Critical states close to the transition have a structure compatible with fractal or multiscale-entangled Griffith states, characterized by entanglement at multiple levels: small strongly entangled clusters are weakly entangled together to form larger clusters.
The critical point therefore features subthermal entanglement and a power-law distributed cluster size, while the localized phase present an exponentially decreasing distribution.
These results are consistent with some of the recently proposed phenomenological renormalization-group schemes characterizing the many-body localized critical point, and may serve to constrain other such schemes.

Keywords: Many, body localization, entanglement, numerics, interactions

*Speaker

Density of states in Ising superconductors

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Transition metal dichalcogenide monolayers (TMDCs) are a new class of two-dimensional superconductors. They host strong intrinsic spin-orbit coupling (SOC) that acts as an effective Zeeman field with opposite, out-of-plane, orientations in the two ±K corners of the Brillouin zone, called valleys. This SOC causes unconventional "Ising pairing" in superconducting TMDCs, whose main signature is a large enhancement of the in-plane upper critical field, as electrons are strongly pinned to out-of-plane orientation and protected from the effect of in-plane fields [1,2,3,4].
We previously found that disorder plays an important role in Ising supeconductors [5]. While intravalley scattering does not modify the superconducting properties, intervalley scattering introduces a pair-breaking mechanism, necessary to explain measurements of the upper critical field.

Using the quasiclassical formalism for disordered Ising superconductors we developed, we calculate the density of states. We show that its behavior is governed by the ratio of the intervalley scattering and the intrinsic SOC, and goes beyond the standard Abrikosov-Gor'kov theory. These results can be used to interpret recent tunneling measurements in high in-plane fields [6], and thus improve current understanding of these novel superconductors.

Y. Saito *et al.*, Nat. Phys. **12**, 144 (2016)

J. Lu *et al.*, Science **350**, 1353 (2015)

X. Xi et al., Nat. Phys. **12**, 139 (2016)

S. C. de la Barrera *et al.*, Nat. Commun. **9**, 1427 (2018)

S. Ilic *et al.*, Phys. Rev. Lett. **119**, 117001 (2017)

E. Sohn *et al.*, Nat. Mat. 17, 504 (2018)

Keywords: superconductivity, disorder, transition metal dichalcogenides

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STM and STS of superconducting nanowires driven out of equilibrium

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Strongly disordered superconductors (MoSi, WSi, TiN, NbN,...) have recently gained a lot of interest for the engineering community, in particular for photon detection, in radioastronomy (KIDs) and telecommunications (SNSPDs). Up to now, only transport measurements over macroscopic samples in the gigahertz range have been performed, and reveal some electromagnetic anomalies preventing optimal detection.
Besides, Scanning Tunneling Microscopy (STM) is the ideal tool to map the electronic properties on a nanometer scale in order to characterize the spatial inhomogeneities in disordered superconductors. Thus, we etched nanowires in order to perform simultaneously transport measurements and scanning tunneling spectroscopy on a superconducting single mesoscopic device, and we succeed in our experimental setup to locate and probe a single superconducting nanowire driven out-of-equilibrium.

A second kind of imaging can be performed with a STM, that we named *scanning critical current microscopy.* In this technique the pair breaking efficiency of the injection of quasiparticle at different energies by the STM tip is deduced by monitoring the critical current of the superconducting nanowire as a function of the tip position. Furthermore, when exposed to a magnetic field, vortices, which carry quantized flux, develop in superconducting films. Their cores bear a singularity of the superconducting order parameter and therefore behave as quasiparticles traps. These vortices can be imaged with an STM by polarizing the tunneling junction near the superconducting gap edge energy.

Up to now, we performed measurements on conventional superconductors, demonstrating the influence of the tunneling current on the superconducting critical current of the nanowire, and pointing out the role of vortices as quasiparticle traps. We are now designing samples with peculiar wire geometries, and moving to disordered superconductors.
The possible correlation of the scanning critical current current microscopy with the geometry, spatial inhomogeneities in the gap amplitude, sub-gap states or vortices will be analyzed. The results will be used to understand better the position dependence of the photon detection efficiency, the role of inhomogeneity in the behavior of superconducting detectors and the competition between the trapping of quasiparticles inside the vortex and the recombination process into Cooper pairs.

Keywords: Charge imbalance, disordered superconductivity, vortices

*Speaker

Topological Phase Transition Driven by Temperature in HgTe/CdHgTe QWs

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Due to their amazing electronic properties, 2D and 3D topological insulators (TI) have attracted increasing attention within the last decade. Simultaneously, HgTe/CdHgTe quantum well (QW) was the first system where the TI state was predicted [1] and experimentally observed.[2] The inversion of electron-like level E1 and hole-like level H1 induces spin-polarized helical edge states.[2] When E1 and H1 levels cross each other, the band structure mimics a linear dispersion of massless Dirac fermions [3] corresponding to the phase transition between trivial band insulator (BI) and TI states. By fabricating QWs with different thicknesses, the band structure can be widely tuned, i.e. it is inverted if QW thickness d exceeds the critical value $dc = 6.3$ nm for $xCd = 0.7$ and QWs grown on CdTe buffer, whereas the band structure is normal for $d < \ dc$.[1] At the critical thickness, the band gap closes, establishing single-valley 2D massless Dirac fermions.[3] In addition to the QW thickness, temperature [4,5] and hydrostatic pressure [6] also induces the transition between BI and TI phases across the critical gapless state. The temperature effect on the band ordering in HgTe/CdHgTe QWs is mainly caused by the lattice expansion and a strong temperature dependence of the energy gap at the point of the Brillouin zone between the 6 and 8 bands in HgCdTe crystals.[7]
One of the inherent properties of inverted band HgTe/CdHgTe QWs is their characteristic behavior under applied magnetic field B, i.e., the crossing of zero-mode Landau levels (LLs) [2], arising at a critical magnetic field Bc. These LLs split from the edge of E1 and H1 subbands and tend toward conduction and valence bands, respectively. Within QWs in the TI phase, zero-mode LLs cross at a critical magnetic field above which the inverted band ordering is transformed into the direct one.[2] In the BI phase, in which E1 level lies above H1 subband, the zero-mode LLs do not cross. The latter can be conditionally interpreted as negative values for Bc. Thus, $Bc = 0$ corresponds to a topological phase transition between BI and TI phases. As it is for the band ordering, a critical magnetic field also depends on temperature and pressure, and therefore, can be varied by tuning these external parameters.[6] By analyzing magnetotransport data at high and low temperatures, S. Wiedmann et al.[5] have experimentally shown that TI

*Speaker

phase vanishes with temperature. However, due to high critical temperature Tc (above 200 K) the gapless state couldn't be directly observed in their samples. A.V. Ikonnikov et al.[8] have reported on magnetospectroscopy of HgTe quantum wells in magnetic fields up to 45 T in temperature range from 4.2 K up to 185 K. They show that although their samples are TI at low temperatures only, the signature of such phase persists in optical transitions at high temperatures and high magnetic fields.

In the present work, we report on the observation of temperature driven topological phase transition by magnetotransport and far-infrared magnetoabsorption spectroscopy. The band structure evolution as temperature arises is clearly observed in our measurements, revealing topological phase transition between TI and BI states at 27 K and 90 K for 6.5 nm and 8 nm thick QWs, respectively.

B.A. Bernevig, T.L. Hughes, S.-C. Zhang, Quantum Spin Hall Effect and Topological Phase Transition in HgTe Quantum Wells, *Science.* 314 (**2006**) 1757–1761. doi:10.1126/science.1133734.

M. Konig, S. Wiedmann, C. Brune, A. Roth, H. Buhmann, L.W. Molenkamp, X.-L. Qi, S.-C. Zhang, Quantum Spin Hall Insulator State in HgTe Quantum Wells, *Science.* 318 (**2007**) 766–770. doi:10.1126/science.1148047.

B. Büttner, C.X. Liu, G. Tkachov, E.G. Novik, C. Brüne, H. Buhmann, E.M. Hankiewicz, P. Recher, B. Trauzettel, S.C. Zhang, L.W. Molenkamp, Single valley Dirac fermions in zero-gap HgTe quantum wells, *Nat. Phys.* 7 (**2011**) 418–422. doi:10.1038/nphys1914.

P. Sengupta, T. Kubis, Y. Tan, M. Povolotskyi, G. Klimeck, Design principles for HgTe based topological insulator devices, *J. Appl. Phys.* 114 (**2013**) 043702. doi:10.1063/1.4813877.

S. Wiedmann, A. Jost, C. Thienel, C. Brüne, P. Leubner, H. Buhmann, L.W. Molenkamp, J.C. Maan, U. Zeitler, Temperature-driven transition from a semiconductor to a topological insulator, *Phys. Rev. B.* 91 (**2015**) 205311. doi:10.1103/PhysRevB.91.205311.

S.S. Krishtopenko, I. Yahniuk, D.B. But, V.I. Gavrilenko, W.M. Knap, F. Teppe, Pressure- and temperature-driven phase transitions in HgTe quantum wells, *Phys. Rev. B.* 94 (**2016**) 245402. doi:10.1103/PhysRevB.94.245402.

F. Teppe, M. Marcinkiewicz, S.S. Krishtopenko, S. Ruffenach, C. Consejo, A.M. Kadykov, W. Desrat, D. But, W.M. Knap, J. Ludwig, S. Moon, D. Smirnov, M. Orlita, Z. Jiang, S. V. Morozov, V.I. Gavrilenko, N.N. Mikhailov, S.A. Dvoretskii, Temperature-driven massless Kane fermions in HgCdTe crystals, *Nat. Commun.* 7 (**2016**) 12576. doi:10.1038/ncomms12576.

A. V Ikonnikov, S.S. Krishtopenko, O. Drachenko, M. Goiran, M.S. Zholudev, V. V. Platonov, Y.B. Kudasov, A.S. Korshunov, D.A. Maslov, I. V. Makarov, O.M. Surdin, A. V. Philippov, M. Marcinkiewicz, S. Ruffenach, F. Teppe, W.M. Knap, N.N. Mikhailov, S.A. Dvoretsky, V.I. Gavrilenko, Temperature-dependent magnetospectroscopy of HgTe quantum wells, *Phys. Rev. B.* 94 (**2016**) 155421. doi:10.1103/PhysRevB.94.155421.

Keywords: topological insulator, phase transition, HgCdTe, Dirac fermions, Terahertz spectroscopy

Magnetotransport in Weyl Nanowires

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We study longitudinal magnetotransport in Weyl semimetal nanowires. We show that depending on radii of nanowires and magnetic field amplitudes there exist two qualitatively and quantitavely different regimes of transport. It is demonstrated that in the strong magnetic field regime (magnetic length much smaller than the radius of the nanowire), Landau level spectrum contains the chiral 0-th Landau level, and thus the transport properties resemble that of a bulk Weyl semimetal. On the contrary, in the weak magnetic field regime (magnetic length much larger than the radius of the nanowire), the lowest-energy band is a Fermi arc surface-bulk state with a non-chiral dispersion, hence there appear transport features distinct from those attained at larger radii or larger magnetic fields. We argue that both regimes are relevant for the ongoing experiments. We also demonstrate that the contribution of Fermi arc surface states is salient and, therefore, crucial for understanding transport properties of finite-size Weyl semimetal systems.

Keywords: Weyl semimetal, magnetotransport, finite, size effects, Fermi arc surface states

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Topological signatures in voltage-biased conventional Josephson junctions

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Topological signatures in voltage-biased conventional Josephson junctions
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Topological phases of matter have attracted much interest in recent years. Topological superconductors are of particular interest because they may host Majorana bound states [1]. As two Majorana bound states are needed to form one ordinary fermion, they would allow one to create nonlocal qubits that are therefore insensitive to local perturbations. Furthermore,the Majorana bound states are non-Abelian anyons such that topologically protected quantum operations may be realized by braiding them.

Josephson junctions have been proposed as probes of topological superconductivity. Transport measurements of voltage-biased junctions have revealed possible signatures of Majorana bound states, The most striking signatures obtained in HgTe quantum wells in (vicinity of) the quantum spin-Hall regime [3,4] have not been fully understood so far. Indeed, theory predicts that such signatures should arise only in the presence of some backscattering mechanism of – most likely – magnetic origin, which could not be identified so far. In order to understand transport through the junction in the presence of a small voltage bias, we have to consider the Andreev bound states formed at the junction and their occupations.

In equilibrium, Josephson junctions host Andreev bound states, whose energy depends on the superconducting phase difference, at energies below the superconducting gap. In a voltage-biased junction, the time-varying superconducting phase difference, which increases linearly with the bias voltage, induces non-adiabatic transitions between lower and higher energy states.

In conventional junctions, these are Landau-Zener processes between two discrete Andreev states [5], while in topological junctions, these are Demkov-Osherov processes between an Andreev state and the quasiparticle continuum in the leads [6].

We propose here a model of a conventional Josephson junction which includes the effect of magnetic impurities. Magnetic impurities create a gap between each Andreev bound state and the continuum. Thus quasi-particles in Andreev bound states can undergo Demkov-Osherov processes between discrete states and the continuum. These processes associated with Landau-Zener process between discrete states can induce a non-trivial occupation dynamics of Andreev bound states. Our model shows the existence of a regime where the noise spectrum of a conventional junction has a 4π-periodic component like a topological Josephson junction.

*Speaker

A.Y. Kitaev, Phys. Usp. 44, 131 (2001)

L.P. Rokhinson et al., Nature Physics 8, 795 (2012)

J. Wiedenmann et al., Nature Communications 7, 10303 (2016)

E. Bocquillon et al., Nature Nanotechnology 12, 137 (2017)

D. Averin and A. Bardas, Phys.Rev.Lett.75, 1831 (1995)

M. Houzet et al., Phys.Rev.Lett.111, 046401 (2013)

Keywords: Majorana anyon:Andreev bound states:noise spectrum:voltage biaised

Emission Noise in an Interacting Quantum Dot: Role of Inelastic Scattering and Asymmetric Coupling to the Reservoirs

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We develop a theory for calculating the noise at finite-frequency in a quantum dot connected to two reservoirs in the presence of interactions and for any symmetry of the couplings to the reservoirs [1,2]. The theory is developed in the non-equilibrium Keldysh Green function technique. We establish an analytical expression for the noise in terms of the various transmission amplitudes between the reservoirs and of some effective transmission coefficient which we define. The obtained expression can be seen as the analog of the Meir-Wingreen formula for the current in the sense that it includes inelastic scattering contributions. We give a physical interpretation of the result on the basis of the transmission of an electron-hole pair to the concerned reservoir where it emits an energy after recombination. The interactions are then treated by solving the self-consistent equations of motion for the Green functions. We find that the noise derivative is zero until the voltage reaches a threshold value set by the measuring frequency, beyond which a Kondo peak appears when the system is in the Kondo regime. Our findings are in very good agreement with recent measurements in carbon nanotube quantum dots [3].

A. Crépieux, S. Sahoo, T.Q. Duong, R. Zamoum, and M. Lavagna, Phys. Rev. Lett. **120** (2018)

R. Zamoum, M. Lavagna, and A. Crépieux, Phys. Rev. B **93**, 235449 (2016)

R. Delagrange, J. Basset, H. Bouchiat, and R. Deblock, Phys. Rev. B **97**, 041412(R) (2018)

Keywords: emission noise, quantum dot, inelastic scattering, strong correlations

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Towards the exponential suppression of dephasing in a superconducting quantum bit

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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. Superconducting circuits are mainly subject to two decoherence channels: energy relaxation and dephasing. In this ongoing experimental work, we aim for exponential suppression of the dephasing channel by taking advantage of non-linear drives and dissipation. The remaining decoherence channel, energy relaxation, could in turn be suppressed by redundantly encoding the information in several of these driven dissipative systems.

Keywords: Superconducting circuits, decoherence, dephasing, quantum error correction, fault, tolerance, quantum information

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Magneto-optical spectroscopic signatures of topological hetero-junction

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Recent studies have revealed multiple surface states, both massless and massive, at the smooth interface between two insulators of opposite topological Z2 indices by transport and ARPES measurements. Here we study theoretically magneto-optical spectroscopic signatures of these surface states in the framework of a 3D isotropic model by calculating the optical conductivity, whose real part links to photon absorption process. Under a magnetic field parallel to the interface, we show that the confinement effect is similar to a pseudo magnetic field which gives rise to Landau bands and competes against the magnetic field. The absorption peaks are right-shifted. However, under a magnetic field perpendicular to the interface, the spectra of absorption reshapes radically and the changes are visible under realistic experimental conditions.

Keywords: magneto, optical spectroscopy, topological hetero, junction, topological insulator, Volkov, Pankratov

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Braiding Majorana zero modes using quantum dots

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We study a network of Kitaev wires coupled to several individually-tunable quantum dots as an extension of the recent experiments on a quantum dot coupled to a nanowire hosting Majorana zero modes. The setup features localized Majorana modes with exact zero energy and we show that they can be manipulated by solely acting on the quantum dots. A braiding process can be obtained by arranging three wires as a trijunction and a charge readout of the quantum dots can be used to reveal the non-Abelian statistics of Majorana zero modes. The setup can be scaled up to serve the more advanced purposes of topological quantum computation.

Keywords: Kitaev wire, Majorana fermions, Braiding

*Speaker

Ultra-long wavelength Dirac plasmons in graphene capacitors

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Graphene is a recognized 2D platform for plasmonics in the THz and mid-infrared domains. These high-energy plasmons couple to the dielectric surface modes giving rise to hybrid plasmon-polariton excitations. The ultra-long wavelength GHz range addresses the low energy end of the spectrum, where Dirac plasmons are damped by ohmic losses but essentially decoupled from the environment. Using hexagonal boron-nitride encapsulated graphene [1] we demonstrate a plasma resonance capacitor [2] showing a quarter-wave plasmon mode, at 40GHz, with a quality factor Q=2. At low doping, or high temperature, ohmic losses take over giving rise to an evanescent wave response [3]. The resolution of the resonant technique yields precise determinations of the electronic compressibility, kinetic inductance, and electronic mean free-path, in good agreement with graphene plasmon theory. The 100 μm long wavelength allows engineering doping-modulated devices where plasmons are controlled by Klein tunneling. Down scaling for room temperature operation opens perspectives in microwave detection for wireless communication and sensing [4].

References

L. Banszerus et al, Nano Lett. 16, 1387 (2016)

H. Graef et al., J. Phys. Mater. 1, 01LT02 (2018)

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E. Pallecchi et al., Phys. Rev. B 83, 125408 (2011)
D.A. Bandurin et al, arXiv:1807.04703 (2018)

Keywords: Graphene, Plasmonics, High, frequency transport, Plasma resonance

Electron waiting times in hybrid junctions with topological superconductors

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We investigate the waiting time distributions (WTDs) of superconducting hybrid junctions, considering both conventional and topologically nontrivial superconductors hosting Majorana bound states at their edges. To this end, we employ a scattering matrix formalism that allows us to evaluate the waiting times between the transmissions and reflections of electrons or holes. Specifically, we analyze normal-metal–superconductor (NIS) junctions and NISIN junctions, where Cooper pairs are spatially split into different leads.
The distribution of waiting times is sensitive to the simultaneous reflection of electrons and holes, which is enhanced by the zero-energy state in topological superconductors.
For the NISIN junctions, the WTDs of trivial superconductors feature a sharp dependence on the applied voltage, while for topological ones they are mostly independent of it. This particular voltage dependence is again connected to the presence of topological edge states, showing that WTDs are a promising tool for identifying topological superconductivity.

Keywords: waiting times distribution, superconducting hybrid junctions, topological superconductors

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Floquet-Tomasch mechanism for long-range correlations between Cooper pairs in a BCS three-terminal Josephson junction

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The Josephson effect originates from tunneling of Cooper pairs between two superconductors, through a non superconducting insulating region. The current-phase relation deviates from sinusoidal for higher transparency: two, three or more correlated Cooper pairs can be transmitted in a single tunneling event. Three-terminal Josephson junctions have been used to implement [1,2] detection of these correlated Cooper pairs, through their splitting into different leads [3]. The phase rigidity of a BCS superconductor has infinite range, but quartets made of two correlated Cooper pairs do no show infinite range phase rigidity, because they originate from the interfaces in absence of glue between Cooper pairs in the bulk. The question is then to put numbers on this length scale, in connection with experimental results [4] obtained at the Weizmann Institute on a double-SQUID interferometer [5]. Extending the 1960s McMillan-Anderson model of Tomasch oscillations leads to an original Floquet-Tomasch mechanism for quantum coherent synchronization between two superconductor-quantum dot-superconductor Josephson junctions biased with significant voltages. The effect combines multiple Andreev reflections at each junction to long-range Tomasch propagation in the electron-hole channel above the gap. Simple physical pictures will be presented, in analogy with the tilted band picture for Wannier resonances in solid state physics. The range is limited by inelastic scattering, also in the dirty limit.

A. H. Pfeffer, J. E. Duvauchelle, H. Courtois, R. Mélin, D. Feinberg, and F. Lefloch, Phys. Rev. B 90, 075401 (2014).

Y. Cohen, Y. Ronen, J.-H. Kang, M. Heiblum, D. Feinberg, R. Mélin and H. Shtrikman, PNAS in press.

A. Freyn, B. Douçot, D. Feinberg, and R. Mélin, Phys. Rev. Lett. 106, 257005 (2011).

R. Mélin, Y. Cohen, Y. Ronen, H. Shtrikman, J.-G. Caputo, R. Danneau and B. Douçot, in preparation (2018).

J. Rech, T. Jonckheere, T. Martin, B. Douçot, D. Feinberg, and R. Mélin, Phys. Rev. B 90, 075419 (2014).

Keywords: Superconductivity, Multiterminal structures, Floquet theory, Tomasch effect

*Speaker

Suppression of quasiparticle poisoning by hard gap filtering

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In the grand scheme of realizing a topological quantum computer, poisoning of superconducting islands by quasiparticle is detrimental as the number of electrons in a quantum dot fluctuates with a high rate. In this talk I will present a study of a possible way around poisoning. We use the combination of a voluntarily 1e poisoned superconducting wire in series with a clean 2e superconducting filter built from an Al/InAs nanowire. I will show how one can use electrostatic gates to deplete the clean part of the wire and isolate the poisoned part from the rest of the circuit. Such scheme effectively protects the system of interest from quasiparticle poisoning. From this study we also extract the superconducting coherence length of the nanowire and show that we can obtain a relatively small poisoning rate while keeping a strong coupling to normal leads.

Keywords: quasiparticle poisoning, transport, semi, supra heterostructure

*Speaker

Topological classification for multiterminal Josephson Junctions

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Topological materials have become the focus of intense research in recent years.They can be classified into an elegant " periodic table " (sometimes called Altland Zirnbauer 10 fold way). Recently, it has been shown that the Andreev bound spectrum (ABS) of a multiterminal Josephson Junction (JJ) can exhibit topological properties similar to the ones which exist in the bandstructure of topological insulators or superconductors. However, due to the anomalous behaviour of the superconducting phases which play the role of quasimomenta, the topology of a N-terminal JJ can not be described by the standard table. Thus, a new classification must be envisionned. Here we propose such a classification, and discuss some of its consequences.

Keywords: topologie classification multiterminal josephson junction superconductors

*Speaker

Influence of microwave radiation on an STM Josephson junction

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The combination of a Josephson junction with the atomic-scale precision of a scanning tunnelling microscope (STM) would enable the measurement of the superconducting order parameter around single magnetic defects. We present here a current-driven Josephson junction in an STM at

Keywords: Josephson effect, microwave, STM

*Speaker

A tunable, high-precision voltage source for mesoscopic physics

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Superconducting circuits based on microwaves-driven Josephson junctions (JJ) have been the recommended way

to realize the voltage standard since 1990[1], because they allow to relate the (highly precise and accurate) frequency

of microwaves to the voltage across the JJ using only fundamental constants[2]. Circuits used for metrological

purpose have historically been designed to reliably provide a constant voltage of about 1 to 10 V in order to calibrate

instruments with an absolute reference.

A cryogenic, highly accurate, and foremost precise (low-noise) voltage source could be of great interest in meso-

scopic physics experiments where cryogenic measurements of weak signals can be limited to 1/f from solid-state

circuitry or thermal noise from cabling to room temperature. Such a source could be used to implement virtually

noise-free parameters, such as small electromagnets, gate voltages or current biases. Voltage-adjustable standards

exist[3], but in order to be useful for physics experiments, such a source would have to be continuously tunable,

a feature that has not been addressed in the context of metrology where focus was placed upon reliability and a

voltage/current range adequate for calibrating standard electronic instrumentation.

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Here we present results on a superconducting circuit meeting the stability requirements[4] for a microwave-driven

Josephson junction to act as a tunable voltage source, operating in a range adequate to mesoscopic physics experiments

(10–400μV, $>$ 100 nA). The source voltage can be adjusted deterministically. Moreover, we show that this adjustment

can be made continuously, with minimal discontinuity in the output voltage.

Possible improvements of the source are discussed, including a higher voltage range and higher current sourcing capabilities, as well as the suppression of any discontinuity.

References :

T. J. Quinn, Metrologia, 26(1), 69-74 (1989)

S. Shapiro, Josephson Currents in Superconducting Tunneling: The Effect of Microwaves and Other Observations, Phys. Rev. Lett.11, 80 (1963)

C. J. Burroughs et al., NIST 10 V Programmable Josephson Voltage Standard System, IEEE Transactions on Instrumentation and Measurement, 60 (7) (2011)

R.L. Kautz, Noise, Chaos, and the Josephson voltage standard, Rep. Prog. Phys.59(1996)

Keywords: métrologie, circuits quantiques supraconducteurs, jonctions Josephson

Landau Velocity for Collective Quantum Hall Breakdown in Bilayer Graphene

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Breakdown of the integer quantum Hall effect (QHE) is associated with an electric field approaching the inter-Landau-level (LL) Zener field Ec, ratio of the Landau gap and the cyclotron radius. The intrinsic Zener limit Ec_˜10ˆ6 V/m , corresponding to critical drift velocity

Keywords: Effet Hall quantique, breakdown, graphene

*Speaker

Time-dependent thermoelectric transport with t-kwant software

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Despite being known for over 200 years, the thermoelectric effects, i.e. the direct conversion of temperature differences to thermal voltage and vice versa, are still only being used in rare and very specific setups due to tiny efficiencies. Both the use of semiconductors since the 1950s and the nanostructuration of materials since the 1990s lead to significant increases of the efficiency, but still nowadays devices achieve only few percents of the thermodynamic limitation, the carnot efficiency. Today's research to increase the thermoelectric efficiency roughly splits into finding best suited materials and geometries on one side and studying effect out-of-equilibrium effects on the other side. Among the latter, time-dependent studies [1-3] showed analytically in the resonant level model that sudden changes of the system can lead to great enhancement of the efficiency compared to the static case.

The purpose of our project is to develop and use tools to study numerically the thermoelectric properties in a time-dependent system. To that end, we want to extend tkwant [4] to the calculation of heat currents. Our first numerical results are in perfect agreement with the analytical formula derived for the resonant level model. We now plan to consider more complicated and realistic systems in order to motivate the first experiments in the field.

A. Crepieux et al., PRB **83**, 153417 (2011)

M. F. Ludovico et al., PRB **89**, 161306(R) (2014)

H. Zhou et al., Scientific Reports **5,** 41870 (2015)

Tkwant is a software library to compute the time-dependent scattering function in tight-binding systems which can therefore be used to calculate time-dependent currents, see: B. Gaury et al., Phys. Rep. **534**,1 (2014)

Keywords: thermoelectricity, out of equilibrium, mesoscopics, transport, time dependent

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Time-dependent thermoelectric transport with the t-kwant software

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Despite being known for over 200 years, the thermoelectric effects, i.e. the direct conversion of temperature differences to thermal voltage and vice versa, are still only being used in rare and very specific setups due to tiny efficiencies. Both the use of semiconductors since the 1950s and the nanostructuration of materials since the 1990s lead to significant increases of the efficiency, but still nowadays devices achieve only few percents of the thermodynamic limitation, the carnot efficiency. Today's research to increase the thermoelectric efficiency roughly splits into finding best suited materials and geometries on one side and studying effect out-of-equilibrium effects on the other side. Among the latter, time-dependent studies [1-3] showed analytically in the resonant level model that sudden changes of the system can lead to great enhancement of the efficiency compared to the static case.
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M. F. Ludovico et al., PRB 89, 161306(R) (2014)

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Keywords: Thermoelectricity, out of equilibrium, time, dependence

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Ballistic electrons splashing down in a Fermi sea

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The one-dimensional, chiral and dissipationless edge channels of the quantum Hall effect form the electrical analogue of optical fibers, allowing the implementation of electron quantum optics experiments where one coherently manipulates the trajectories of single electronic wave packets [1]. A recent series of experimental and theoretical works have put into light strong effects of decoherence and energy relaxation caused by interactions with quasiparticles present in neighboring edge channels, capacitively coupled to the edge channel in which the experiment is performed [2,3]. This coupling leads to new eigenstates of transport in quantum Hall edge channels, challenging the usual representation of transport in the quantum Hall effect in terms of fully independent edge channels.
We have experimentally investigated the energy relaxation undergone by a steady stream of electrons emitted at a well-defined energy in a quantum Hall edge channel, in presence of a second edge channel copropagating along the former. Our setup relies on a pair of electrostatically defined quantum dots, used as energy-resolved emitter and detector. The emitter is realized by applying a finite drain-source voltage on the first quantum dot, with a single resonant level in the bias window, the position of which sets the energy at which electrons are emitted above the drain Fermi energy. After a tunable propagation length in the micrometer scale, we perform an energy spectroscopy of the emitted electrons using the second quantum dot as an energy filter [4]. This detection technique was previously used to characterize the energy relaxation for an out-of-equilibrium energy distribution of electrons generated in a quantum point contact [5].

Our results, obtained at filling factor 2 of the quantum Hall effect, show that although the propagation over submicron lengths leads to sizable energy relaxation, a small portion of quasiparticles are not affected by energy relaxation even at relatively high energies, up to 170 μeV. Surprisingly, we observe that the amount of energy lost during propagation is markedly larger than expected [6], suggesting that relaxation mechanisms towards external degrees of freedom play an important, unexpected role in electron quantum optics experiments.

E. Bocquillon, *et al.,* Annalen der Physik 526, 1 (2014).

I. Levkivskyi, *et al.,* PRB 85, 075309 (2012).

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E. Bocquillon, *et al.,* Nat. Commun. 4, 1839 (2013).

C. Altimiras, *et al.,* Nature Physics 6, 34 (2009).

H. le Sueur, *et al.,* PRL 105, 056803 (2010).

C. Grenier et al, Mod. Phys. Lett. B 25, 1053 (2011).

Keywords: Quantum Hall Effect, Edge States, Energy Relaxation

Toward flying qubit spectroscopy

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While the coherent control of two level quantum systems -qubits- is now standard, their continuum electronic equivalents -flying qubits- are much less developed. A first step in this direction has been achieved in DC interferometry experiments. Here, we propose a simple setup to perform the second step, the spectroscopy of these flying qubits, by measuring the DC response to a high frequency AC voltage drive. Using two different concurring approaches - Floquet theory and time-dependent simulations - and three different models - an analytical model, a simple microscopic model and a realistic microscopic model - we predict the power-frequency map of the multi-terminal device. We argue that this spectroscopy provides a direct measurement of the flying qubit characteristic frequencies and a key validation for more advanced quantum manipulations.

Keywords: Interferometer flying qubit

*Speaker

Strong electronic quantum interferences between two 0.1 mm long quantum Hall edge paths

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Direct observations of electronic quantum interferences in solid-state conductors remained up to now limited to propagation paths shorter than 30 μm independently of the material, whether it consists of a diffusive metal, a ballistic semiconductor heterojunction or a 2D graphene sheet. This poster presents first data demonstrating strong quantum interferences between electrons propagating over 0.1 mm along two separate pathways in a circuit. Interferences of visibility as high as 80% and 45% are observed on electronic analogues of the Mach-Zehnder interferometer of, respectively, 24 and 100 μm arm length, consistently corresponding to a 0.25 mm electronic phase coherence length. While such devices perform best in the integer quantum Hall regime at filling factor 2, the Coulomb interaction between co-propagating edge channels usually impedes electronic interferences. Expanding upon **[1, 2]**, we overcome this limitation by selectively closing the inner channel in isolated micron-scale loops, thereby freezing these electronic degrees of freedom and giving rise to an important increase of the electron quantum coherence length.

[1] *Quantum coherence engineering in the integer quantum Hall regime*, PA Huynh, *et al.,* Physical Review Letters **108**, 256802 (2012)

[2] *Tuning energy relaxation along quantum Hall channels*, C Altimiras, *et al.,* Physical Review Letters **105**, 226804 (2010)

Keywords: Coherence length, Quantum Hall effect

*Speaker

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A Casimir Effect in Quantum Mesoscopic Physics

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Casimir forces, or fluctuation induced forces, are ubiquitous, and result from the confinment of long-ranged fluctuations. Casimir forces have been first predicted and measured using conducting plates immersed in the quantum (QED) vacuum, then in classical systems, in biophysics, in condensed matter and in out-of-equilibrium hydrodynamic systems.
Here, we consider intensity fluctuations of classical light propagating through a scattering medium. In the elastic multiple scattering regime, the average light intensity behaves diffusively, and can be described using an effective Langevin equation, where a properly tailored noise accounts for mesoscopic coherent effects. Light intensity fluctuations are spatially long-ranged as a result of underlying mesoscopic coherent effects. Their magnitude depends on the dimensionless conductance g - a parameter which depends on the scattering properties of the system and on the geometry.
Using the mapping with out-of-equilibrium systems provided by the Langevin equation, we show the emergence of fluctuation induced forces for coherent diffusive light, which can be measured.

Keywords: Casimir effect, coherent light, out, of, equilibrium physics

*Speaker

Microscopic charged fluctuators as strong source of decoherence in disordered superconductor devices

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Using experiments made with high impedance superconducting resonators made of highly disordered NbSi alloy, we bring to light a new mechanism causing strong decoherence in all disordered superconductor setups. This mechanism is based on the direct coupling of charged TLSs to the conduction electrons and can be analysed within the standard framework of mesoscopic transport. Interestingly, this decoherence mechanism occurs already in the BCS ground state, without any out-of-equilibrium quasiparticles, vortices, etc. This mechanism and the omnipresence of charged TLSs easily explains at once the poor coherence of Quantum Phase Slip devices and the internal losses of disordered superconductor resonators; it potentially affects all experiments involving disordered superconductors, including those investigating the SIT or the BKT phase transitions.

Keywords: disordered superconductor, decoherence, quantum phase slip, resonators

*Speaker

Caractérisation des lévitons en effet Hall fractionnaire

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Récemment, le groupe de Christian Glattli a implémenté une méthode d'injection d'électron unique à la demande ("léviton") dans un conducteur quantique bidimensionel [1]. Fondée sur une proposition théorique de L. Levitov & al [2], elle consiste à appliquer sur le conducteur une série périodique de pulsations lorentziennes. Cette avancée ouvre la possibilité de générer des qubits volants, ainsi que de réaliser des expériences d'interférométrie permettant d'explorer la statistique de ces excitations.
Mon travail de thèse consistera à générer et caractériser ces lévitons en régime d'effet Hall entier et fractionnaire. D'une part, nous souhaitons mettre en évidence le bruit poissonien du courant tunnel entre deux états de bords prédit pour des pulsations lorentziennes ([3], [4]). De plus, nous envisageons de réaliser des expériences de type Hong-Ou-Mendel (HOM) afin d'obtenir des informations sur la statistique.

Nature 502, 659–663 (2013)

J. Math. Phys. 37, 4845 (1996)

[3] I.Safi, arxiv :1401 :5950
[4] J. Rech et al, Phys. Rev. Lett. 118, 076801 (2017)

Keywords: Effet Hall fractionnaire, bruit quantique, lévitons

*Speaker

Conductance and charge susceptibility of a double quantum dot

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We calculate the charge susceptibility and the conductances of a double quantum dot coupled to two metallic reservoirs both at equilibrium and when the system is driven away from equilibrium. This work is motivated by recent progress in the realization of solid state spin qubits. The calculations are performed by using the Keldysh nonequilibrium Green function technique. In the noninteracting case, we give the analytical expression for the electrical current and deduce from there the linear conductance as a function of the gate voltages VG1 and VG2 applied to each dot, leading to a characteristic charge stability diagram. We then determine the charge susceptibility of the system and point out the formation of two arcs in its 2D representation in the (VG1, VG2) plane and discuss the role of interdot transitions. We finally analyze the effect of an asymmetry in the coupling of the dots to the leads as well as of an asymmetry in the geometry controlling the gate lever on the chemical potential in each dot. We show how the study can be extended to the case of an interacting double quantum dot.

Keywords: Spin qubit, double quantum dot, Green functions

*Speaker

NbN microwave superconducting resonators for silicon quantum spintronics

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Quantum computing is a major new frontier in technology promising computing power unattainable by conventional computers. Many different materials and approaches have been explored so far, with an increasing effort on scalable implementations based on solid- state platforms. Among these, silicon is emerging as a promising route to quantum computing with true potential in terms of scalability and manufacturability. With the recent development of spin-orbit qubit based on hole in silicon [1], it is nowadays conceivable to use a microwave photon as a " quantum bus " for long distance spin-orbit qubit interaction. The strong spin/photon coupling has been recently achieved using an engineered spin-orbit interaction with electron spin in silicon [2,3] or in carbon nanotube [4], our goal here is to use the intrinsic spin-orbit term in the valence band of silicon to achieve this coherent spin/photon coupling.

Here we will present our co-integration project : a CMOS silicon spin qubits embedded in a NbN superconducting microwave resonator. he use of NbN, a disordered superconductor, should allow us to fabricate high kinetic inductance resonators able to couple the photon field of the cavity to the hole spins in silicon via the spin-orbit interaction. We will also present our preliminary results on NbN deposition and resonators fabrication together with our first attempt to extract the kinetic inductance of our NbN layers.

R. Maurand et al. A CMOS silicon spin qubit. Nature Comm. 7, 13575 (2016)

N. Samkharadze et al. Strong spin-photon coupling in silicon. Science 10.1126 (2018). [3] X. Mi et al. A coherent photon interface in silicon. Nature 555, 599 (2018).

J. Viennot et al. Coherent coupling of a single spin to microwave cavity photons. Science 349, 6246 (2016)

Keywords: cQED, qubit, spin/photon interaction

*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 nanowires with strong spin-orbit interaction connected to superconductors. Theoretical proposals have suggested inducing a spin-orbit coupling through a magnetic texture. 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 magnetic gate and coupled to two superconducting electrodes. We observe subgap states in the conductance. A detailed study of their magnetic field evolution reveals a large synthetic spin-orbit energy. Furthermore, a robust zero energy state, the hallmark of localized Majorana modes, emerges at zero magnetic field.

Keywords: Majorana fermions, mesoscopic circuits, induced superconductivity

*Speaker

Single-shot high fidelity qubit readout using a transmon molecule in a 3D cavity

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Using the transverse dispersive coupling between a qubit and a microwave cavity is the most common read-out technique in circuit-QED. However, despite important progresses, implementing a fast high fidelity readout remains a major challenge. Indeed, inferring the qubit state is limited by the trade-off between speed and accuracy due to Purcell effect and unwanted transitions induced by readout photons in the cavity. To overcome this, we introduce a transmon molecule circuit design coupled to a 3D-cavity [1,2]. This system presents one transmon qubit with a large direct cross-Kerr coupling to a weakly anharmonic mode, called polaron mode. This polaron mode results from the hybridization between the microwave cavity and the second mode of the transmon molecule circuit and is used to readout the qubit state. Direct cross-Kerr coupling is a key point to our readout scheme since such a coupling is immune to Purcell effect. We will present qubit readout performance with fidelity as high as 97%. We will also present quantum trajectories with high time resolution and discuss the quantum non-demolition properties of this novel readout.

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É. Dumur, et al, Phys. Rev. B 92, 020515(R) (2015).

É. Dumur, et al, IEEE Trans. On Appl. Supercond. 26, 1700304 (2016).

Keywords: Qubit readout, Josephson junction, transmon, superconducting quantum circuit

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Towards an improved programmable quantum qurrent generator

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Within the context of the future revision of the International System of Units (SI), the ampere definition will be linked to the elementary charge

Keywords: Metrology, Quantum Hall resistance standard, Josephson voltage standards

*Speaker

Magnetoplasmon of 2D fermion on a sphere

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In a first part we report on the physics of 2D Dirac fermions on a sphere. The RPA responses of the 2D fermions to a multipole external field are calculated. The magneto excitation of collective plasmon states are characterized versus the size

Keywords: magetoplasmon, 2D Dirac fermion, sphere

*Speaker

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