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Poster list

Absence of Charge Drift in a Cooper Pair Box

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Résumé

A Cooper pair box is a Josephson junction shunted by a capacitor. The number of charges on the capacitor has an equilibrium value, named the charge offset. All experiments to date have observed that the charge offset drifts over a time, typically of the order of 10 minutes. The transmon is a Cooper pair box specifically designed to suppress the detrimental impact of charge offset fluctuations on qubit dephasing. The frequency dispersion can be made arbitrarily small owing to its exponential dependence on the ratio between the Josephson energy and the charge energy, but the charge offset can still be measured using highly excited states. I will present an experiment on a transmon where we observed stable transition frequencies between highly excited states of a transmon over more than a week. While transmon transition frequencies do not drift, each one jumps between two values corresponding to even and odd charge parities. We show that the observed transition frequencies correspond to a fixed value of the charge offset equal to zero. We attribute this exceptional stability of the charge offset to specific properties of the circuit design, namely the fact that the circuit is made of tantalum on sapphire and that one electrode of the transmon, all superconducting resonators and the drive lines are all connected to ground.

*Intervenant

Exploring Non-Linear Kinetic Inductance in Disordered Superconducting NbN thin films

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Résumé

We present our investigation of non-linear kinetic inductance circuits based on superconducting disordered niobium nitride (NbN) films. This material is promising for advanced electronic applications due to its magnetic field and temperature resilience at microwave frequencies (1).
In our study, we have characterized DC-current-biased microwave resonators fabricated from a thin NbN film with high kinetic inductance. We analyze the relationship between the nonlinearity of the kinetic inductance, measured through the frequency dependence of our resonator at GHz frequencies and the depairing current, measured with DC current via the magnetic field film critical temperature dependence (2).
Our findings contribute to the growing body of knowledge on high kinetic inductance superconducting materials and their potential in quantum technologies.
(1) Yu et. al. "Magnetic field resilient high kinetic inductance superconducting niobium nitride coplanar waveguide resonators",
Appl. Phys. Lett. 118, 054001 (2021).
(2) Clem et. al. "Kinetic impedance and depairing in thin and narrow superconducting films", Phys. Rev. B. 86, 174521 (2012).

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Quasiparticles interferences

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Résumé

We study a non interacting electron model defined on a $\alpha - T_3$lattice, whichexhibits3bandsfeaturingatunablegeome

*Intervenant

Observation of Kekulé vortices around hydrogen adatoms in graphene

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Résumé

Fractional charges are one of the wonders of the fractional quantum Hall effect. They are also anticipated in two-dimensional hexagonal lattices under time-reversal symmetry-emerging as bound states of a rotating bond texture called a Kekulé vortex. However, the physical mechanisms inducing such topological defects remain elusive, preventing experimental realization. Here, we report the observation of Kekulé vortices in the local density of states of graphene under time-reversal symmetry. The vortices result from intervalley scattering on chemisorbed hydrogen adatoms. We uncover that the vortex winding is reminiscent of the Berry phase π of the massless Dirac electrons.

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Résumé

We present our investigation of non-linear kinetic inductance circuits based on superconducting disordered niobium nitride (NbN) films. This material is promising for advanced electronic applications due to its magnetic field and temperature resilience at microwave frequencies (1).
In our study, we have characterized DC-current-biased microwave resonators fabricated from a thin NbN film with high kinetic inductance. We analyze the relationship between the nonlinearity of the kinetic inductance, measured through the frequency dependence of our resonator at GHz frequencies and the depairing current, measured with DC current via the magnetic field film critical temperature dependence (2).
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(2) Clem et. al. "Kinetic impedance and depairing in thin and narrow superconducting films", Phys. Rev. B. 86, 174521 (2012).

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Magnetotransport in shaped topological insulator nanowires

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Résumé

Mesoscopic physics deals with micron-scale objects that, despite being composed of trillions of constituents, exhibit behavior characteristic of single quantum entities. One prominent example is 3D topological insulator nanowires, which feature insulating bulk cores surrounded by highly conductive Dirac-like surface states. At low temperatures, the electrons in these wires traverse as quantum waves of (pseudo)relativistic nature, with their magnetotransport properties dominated by quantum interference. This interference is influenced by external magnetic fields and the system's Berry curvature, as demonstrated in recent experimental collaborations (Ziegler et al., Phys. Rev. B 97, 035157 (2018)).

Subsequent work revealed that the geometrical shape of nanowires significantly impacts their magnetotransport behavior (Kozlovsky et al., Phys. Rev. Lett. 124, 126804 (2020); Graf et al., Phys. Rev. B 102, 165105 (2020)). In these shaped nanowires, Dirac-like electrons effectively propagate in curved space, experiencing gravitational-like effects at quantum scales. While this analogy to black hole physics is striking, nanowires, unlike black holes, can be experimentally realized in the lab.

This rapidly advancing field presents two pressing questions: (i) How are surface states altered in curved space? (ii) Can quantum transport signatures of effective gravitational effects be observed in realistic setups? Addressing these questions requires a combination of analytical approaches and tight-binding numerical simulations.

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Charge sensing-induced decoherence in an electronic two-level system

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Résumé

While continuous measurements of a quantum system play a crucial role in quantum technologies (quantum error correction, quantum metrology...), it requires a constant coupling between the quantum system and a detector, inducing possible back-action effects that can reduce the coherence of the system.
Here, we investigate the effect of a charge detector made of a quantum dot on a two levels system consisting of a double quantum dot and coupled to a photon cavity. Through RF reflectometry measurements, we demonstrate that decoherence within the DQD increases as current flows across the detector.

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Electrically tunable Josephson parametric amplifier based on graphene Josephson junctions

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Résumé

Quantum limited parametric amplifiers are crucial components in the field of superconducting quantum circuits. They are essential to readout of qubits with the best fidelity . There have been developments in recent years to use semiconductor weak links as an electrically tunable source of nonlinearity as a building block of these low noise amplifiers(1,2,3,4). We use graphene Josephson junctions as the semiconductor weak links to demonstrate a gate tunable Josephson Parametric amplifier. Our previous work exhibited such devices operating in the 4 Wave mixing regime with a gain of 20dB and about 1 GHz of frequency tunability with a gate voltage. We present our efforts in developing a parametric amplifier with graphene Josephson junction working in the three wave mixing regime. This regime has the added benefit of easier filtering of the pump tone along with minimized Kerr frequency shift.

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Optomechanical oscillator network for neuromorphic computation

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Résumé

As neural networks develop to tackle increasingly complex tasks, we are witnessing a rapid growth in the computational resources required. In this context, designing a physical implementation of a neural network provides an exciting alternative (1). We consider a system of coupled phase oscillators, namely optomechanical oscillators (2,3), with the aim of leveraging their non-linear behaviour to perform neuromorphic computing. We investigate the possibility of using this kind of network to execute simple tasks based on supervised learning. (1) D. Marković, A. Mizrahi, D. Querlioz, J. Grollier, Nature Reviews Physics 2, 499 (2020).

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Searching for voltage switching of Josephson junctions under strong microwave drive

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Résumé

Josephson junctions realize a superconducting version of the quantum pendulum. Under sufficiently strong drive, a classical pendulum will enter rotating states, which formally correpond to finite-voltage states when translated to the Josephson junction. This has been studied through DC measurements of the corresponding Shapiro steps. However, in microwave circuits, such voltage states should still be reachable under the right conditions for junctions without a DC shunt. We try to reach and study such "zero-bias steps" using microwave techniques, expecting clear transitions in the junction's microwave response. This could pave the way to manipulating the dynamical voltage states V of junctions in the quantum regime.

*Intervenant

Anyon braiding in the time-domain

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Résumé

Recent experiments have evidenced anyons, quasiparticles that keep a memory of particle exchanges via a braiding phase factor (1-5). This provides them with unique dynamical properties so far unexplored. We investigate here the dynamics of anyon tunneling in the time domain by using triggered anyon pulses incident on a quantum point contact (QPC) in a = 1/3 fractional quantum Hall (FQH) fluid.
When an anyon excitation is emitted toward a QPC in a FQH fluid, this memory property translates into tunneling events that may occur long after the anyon excitation has exited the QPC. The dominant mechanism for particle transfer is not the direct tunneling of the incoming excitations, but rather a braiding process between the incoming excitations and particle-hole excitations created at the QPC (5,6,7). Anyon tunneling is then governed by the mutual braiding phase theta*N between the generated anyon pulses and the topological anyons tunneling at the QPC, where is the number of anyons carried per pulse and theta = 2pi/3 is the anyon braiding phase at = 1/3.

By triggering anyon emission at the input of the QPC, we probe the characteristic timescale for anyon tunneling and demonstrate the influence of anyon braiding mechanisms on this timescale (8,9). We observe two different regimes. When braiding is present (theta*N< 2pi), the characteristic timescale for anyon tunneling is set by the temporal decay of the anyon correlation function which is inversely proportional to the temperature and the anyon scaling dimension. In contrast, when braiding is absent (theta*N=2pi), we observe that the characteristic tunneling timescale is set by the temporal width of the generated pulses, as one would naively expect.

This experiment introduces time-resolved measurements for characterizing the scaling dimension and braiding phase of anyons.

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Modifying the electronic properies of the quantum dots with cavity

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Résumé

Hybrid quantum systems with a few electrons, such as quantum dots, have gained growing attention in cavity quantum electrodynamics for their potential to achieve ultrastrong light-matter interactions. These systems provide streamlined architectures that can notably enhance and optimize electron-photon coupling. In this study, we begin by examining how electronic transport is modified within single and double quantum dot arrays placed inside the cavity.

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Scattering approach to near-field radiative heat transfer

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Résumé

We formulate an effective quantum scattering theory for the problem of near-field radiative heat transfer in linear electric circuits. Built from the same ingredients as the semiclassical fluctuational electrodynamics, the standard tool to handle this problem, our construction enables one to calculate arbitrary correlation functions of the energy current, while the fluctuational electrodynamics can be used only for the average current. We give a general expression for the energy current fluctuations in terms of the circuit's scattering matrix and show that it has an important non-dissipative contribution that can dominate the finite-frequency noise while being absent in the average current.

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Superconductivity in Two-Dimensional Electron Gases Based on KTaO (111)

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Résumé

The recent discovery of a superconducting two-dimensional electron gas (2-DEG) in (111)-oriented KTaO-based heterostructures has injected new momentum into the study of oxide interfaces(1,2). Remarkably, this 2-DEG coexists with strong Rashba spin-orbit coupling (3) and is considered a promising candidate for the realization of topological superconducting phases. In this study, we explore superconductivity in 2-DEGs formed at the interfaces between KTaO (111) and AlOx(4). We present a scaling analysis of the superconductor-insulator quantum phase transition driven by an external magnetic field. The results demonstrate the presence of a critical magnetic field, Bc, and a set of universal critical exponents, which suggest a percolative transition. Additionally, we present tunneling spectroscopy measurements of the superconducting energy gap, which indicate a dominant s-wave superconducting order parameter consistent with the BCS weak coupling regime. However, in-gap structures suggest the presence of a second order parameter, primarily revealed under the influence of a magnetic field. These findings underscore the potential of KTaO-based oxide interfaces as a new platform for developing quantum devices, including spintronic and topological devices.

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Dirac quantum Hall states on (negatively) curved surfaces

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Résumé

The geometry of a physical system is intimately related to its spectral properties, a concept colloquially referred to as "hearing the shape of a drum". Electrons in a three-dimensional topological insulator nanowire occupy Dirac states existing on the nanowire curved surface, and organise into quantum Hall states in a strong magnetic field. Such states represent the paradigmatic quantum system with non-trivial geometric response, while nanowire shapes can nowadays be smoothly controlled at the nanoscale. We thus ask how deforming the "drumhead" – the nanowire shape – affects the "soundwaves" – the Dirac quantum Hall states. We show that the surface quantum Hall spectrum splits into two qualitatively different branches, one geometry-dependent and one asymptotically insensitive to the surface shape. The geometry-sensitive branch is however shared with a different surface connected to the original one by a reciprocity relation. For the case of a cone-shaped nanowire, such a branch has a reciprocal quantum Hall spectrum independent of the magnetic field strength in a wide parameter range. We also numerically verify a conjecture on the generalisation of the reciprocity relation to (almost) arbitrary axially-symmetric surfaces. We focus
on Tesla-range magnetic fields and geometries within reach of current experimental capabilities.

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Quantum kinetic equation and thermal conductivity tensor for neutral bosons

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Résumé

We systematically derive the quantum kinetic equation in full phase space for any quadratic Hamiltonian of bosonic fields, including in the absence of translational invariance. This enables the treatment of boundaries, inhomogeneous systems, and states with nontrivial textures, such as skyrmions in the context of magnetic bosons. We relate the evolution of the distribution of bosons in phase space to single-electron, band-diagonal physical quantities such as Berry curvature and energy magnetization by providing a procedure to "diagonalize" the Hamiltonian in phase space, using the formalism of the Moyal product. We obtain exact equations, which can be expanded order by order, for example, in the "smallness" of the spatial gradients, providing a "semiclassical" approximation. In turn, at first order, we recover the usual full Boltzmann equation and give a self-contained and exact derivation of the intrinsic thermal Hall effect of bosons. The formulation clarifies the contribution from "energy magnetization" in a natural manner, and does not require the inclusion of Luttinger's pseudogravitational field to obtain thermal transport quantities.

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DC-biased Josephson junctions for the parametric coupling of quantum systems

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Résumé

Quantum parametric processes can be used to exchange photons between different oscillators in a quantum-coherent manner. They are a powerful tool for various quantum technologic applications, from quantum-limited amplification and sensing to quantum computing as they allow the stabilization of bosonic qubits. Here we propose an original way to activate these processes, via inelastic Cooper pair tunneling through a voltage-biased Josephson junction. We demonstrate the coupling of a dc-SQUID to a long-lived "memory" mode and a lossy "buffer" mode at different frequencies. We study various parametric processes between the two oscillators through the spectroscopy of the buffer, demonstrating large coupling constants, and we propose a protocol to reduce the dephasing induced by the bias voltage fluctuations via injection-locking of the junction's superconducting phase.

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Slave-spin representation of the superconducting Anderson impurity model

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Résumé

We study a strongly interacting quantum dot connected to two superconducting leads. By means of a slave-spin method, the superconducting Anderson impurity model is mapped onto two easier problems which have to be solved self-consistently: a non-interacting superconducting quantum dot with renormalized hopping and a spin-1/2 in a fictitious field. Remarkably, this method captures the Kondo effect at the mean-field level, allowing for a semianalytical treatment of the problem in a regime where superconducting correlations and Kondo correlations coexist.

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Towards a Fermio-Bosonic Qubit

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Résumé

We propose a novel superconducting circuit aiming at more robust quantum states, and featuring two distinct quantum degrees of freedom. It consists in the parallel combination of a large inductance, a capacitor and a quasi-ballistic single-channel weak link. The large inductance results in large fluctuations of the phase across the weak link. The weak link implements a Josephson coupling that depends on an internal fermionic degree of freedom associated with the Andreev level. The electromagnetic modes of the circuit depend on the fermionic occupation, leading to a "fermio-bosonic" qubit.

We present preliminary estimations of the coherence times for this system, taking into account the effects of external flux noise and weak link channel reflectivity. These estimations indicate promising coherence properties that support the feasibility of implementing robust quantum states in this architecture. I will also report recent advancements in the fabrication and microwave characterization of the high inductance based on a Josephson junction array (JJA), and the implementation of a fluxonium circuit with a conventional Josephson junction coupled to a JJA as a readout resonator.

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Low-temperature and low-frequency dissipation in strongly disordered superconductors

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Résumé

In conventional BCS superconductors, the real part of the conductivity, $\sigma 1(\omega$, T), typically shows a monotonic suppression with decreasing temperature, driven by the exponentially low density of quasiparticles. In this study, we report a nonmonotonic temperature dependence of the quality factor Q (T) $\sigma 1$ in microwave resonators made from the strongly disordered pseudogapped superconductor, amorphous InOx. This material is known to deviate from standard BCS behavior (1, 2, 3). To explain the observed behavior of Q, we calculate $\sigma 1(\omega$, T), employing a combination of analytical and numerical methods that capture the spatial inhomogeneity of the order parameter in strongly disordered superconductors with a pseudogap. The results reproduce the nonmonotonic temperature dependence and predict a steep frequency dependence of $\sigma 1$. Both features primarily arise from a broad distribution of the superconducting order parameter (1, 2), which persists even when the system is moderately distant from the superconductor-insulator transition. This observation underlies our proposal to experimentally probe the distribution of the order parameter in strongly disordered superconductors. Alongside recent observations on the temperature suppression of the superfluid stiffness (3), our findings further advocate the existence of localized low-energy collective excitations. Our results have significant implications for the utilization of strongly disordered superconductors in quantum circuits, particularly in enhancing superinductance.

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