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Experimental test of Kubo formula on a quantum conductor driven out-of-equilibrium

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Kubo formula relates the admittance of a quantum conductor to the difference of its absorption and emission noise. In order to test it experimentally, we couple an SIS tunnel junction to a RF detection circuit. In a first step, we follow the prediction of Lesovik and Loosen (1) and show that both emission and absorption noises of the conductor can be extracted from the power it exchanges with a linear detection mode having an adjustable occupation number. In a second step, we measure independently the SIS junction admittance via coherent RF reflectometry. Comparing its real part to the difference of absorption and emission noise measured via power exchanges, we find that Kubo formula holds within our experimental accuracy (2). Our results show that non-symmetrized current fluctuations are imprinted in the measurements of power exchanges, but also stress that Kubo formula holds for non-linear conductors even when driven far from equilibrium.

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Current-induced light emission in single-molecule STM nanojunctions

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The scanning tunneling microscope (STM) is a powerful tool in nanotechnology. Not only such device enables to explore and image the complex physical and chemical properties of molecules with atomic resolution, but also it can be used to emit light, thus playing the role of a new current-induced source of photons at the nanoscale (1). The understanding and control of the light-emission mechanism in such plasmonic nanojunctions is of crucial importance in this field of research, but is rather complex and still incompletely understood (2).
In this presentation, we provide some recent theoretical investigations of the statistics of photon emission in a STM nanojunction hosting one molecule inside the plasmonic cavity (3,4,5,6). In the case of a molecule with a single-energy level that is relevant in the bias window, we investigate some aspects of the mechanism describing plasmon-molecule interactions and light-emission in such nanojunctions (3,4,5). This involves an interplay between single-electron charging or discharging events and the ultrafast dynamics of the cavity plasmonic electromagnetic environment.

We show that upon proper tuning of the junction external electrical biases, it could be possible to design innovative current-induced single photon sources of interest (3,4,5). We compute and characterize the statistics of light-emission out of such devices, showing the conditions for observing a crossover from photon bunching to photon antibunching in the emission process.

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A heat-resilient hole spin qubit in silicon

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Electrically controlled spin qubits are rapidly progressing toward scalability, with multi-qubit processors demonstrated in Group IV semiconductors, up to six qubits in silicon and ten in germanium. However, the simultaneous operation of several qubits has been shown to degrade their individual performance, likely due to local heating from control pulses and the thermal susceptibility of spin qubits, i.e., the temperature dependence of their Larmor frequencies.
In this work, we study the thermal susceptibility of a hole spin qubit in silicon. Owing to spin-orbit coupling, hole spins exhibit a strong anisotropic response to magnetic fields. In particular, their longitudinal spin-electric susceptibility (LSES), the sensitivity of the Larmor frequency to gate voltage, varies with magnetic field orientation and can vanish at specific "sweet spots."

By measuring how the Larmor frequency evolves with temperature, we demonstrate that hole spins also exhibit thermal susceptibility, reaching values up to 10MHz/K, similar to electron spins in silicon. Rotating the magnetic field reveals a strong correlation between electrical and thermal susceptibilities, pointing to a shared origin rooted in spin-orbit interaction.

We propose a microscopic model involving a bath of electric dipoles that thermally activate and alter the local electric field experienced by the qubit. Numerical simulations with randomly distributed dipoles reproduce experimental observations and suggest a surprisingly small dipole moment of ˜1e·pm. Crucially, we identify magnetic field orientations for which the Larmor

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frequency becomes temperature-independent.

This work provides both a physical understanding of spin thermal susceptibility and practical strategies to suppress it, offering a route to protect hole spin qubits against heating effects, even at millikelvin temperatures.

Tensor networks for classical (frustrated) spin systems

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Over the past three decades, tensor networks have become a powerful numerical framework for studying quantum many-body systems. Their usefulness for investigating classical statistical mechanics models is, however, less widely known. In this talk, I will briefly introduce these tensor network approaches before focusing on their application to classical frustrated magnets. Even deceptively simple finite-range antiferromagnetic Ising models on frustrated lattices can exhibit exotic phases and unconventional phase transitions. Yet, the same features that make them interesting – macroscopic ground-state degeneracy and local constraints – also make them challenging to study numerically. I will discuss what studying frustrated magnets teaches us about tensor networks, and conversely, how tensor networks can help us characterize frustrated models on the kagome lattice.

*Speaker

Anyon braiding on the single edge of a fractional quantum Hall state

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Anyons are quasiparticles with fractional statistics, bridging between fermions and bosons. We propose an experimental setup to measure the statistical angle of topological anyons emitted from a quantum point contact (QPC) source. The setup involves an droplet along a fractional quantum Hall liquid edge, formed by defining a droplet with two negatively biased gates. In the weak tunneling regime, we calculate the charge current, showing its time evolution depends solely on the anyons' statistical properties, with temperature and scaling dimension affecting only the constant prefactor. We compute the cross-correlation between the anyon current transmitted from the source and the current after the junction, providing a direct method to detect anyon braiding statistics. Our model can be extended to take into account edge-to-edge capacitance in the droplet. Using Dyson's equation, we are able to encode this effect in the Green's functions of the fractional quantum Hall effect. We explain how to correct the measurement of braiding statistics from cross correlations.

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Spin-orbit proximity effect in bilayer graphene - TMD heterostructures

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Combining 2D materials can modify their properties and make new ones emerge. An illustration of such a combination is (multilayer) graphene in contact with a semiconducting transition metal dichalcogenide (TMD), in which it was shown that the presence of the TMD enhances the superconductivity in bilayer and trilayer graphene (1,2).
A less exotic effect is that a TMD possessing a large intrinsic spin-orbit coupling (SOC), placed in contact with graphene induces significant SOC in graphene (3–5), where it would otherwise be comparatively negligible. In this presentation, I will report of such proximity induced spin-orbit coupling in a bilayer graphene-MoS2 heterostructure (6). We could identify and quantify both a Rashba- and an Ising-SOC contribution. In addition, we relate the non-monotonic conductivity with displacement field at charge neutrality to the single-particle Ising-SOC gap.

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Exploring the Ultra-Strong Coupling Regime in Nanomechanical Quantum Rabi Systems

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The quantum Rabi model has been investigated for several decades, predominantly in the context of optical systems where the coupling between a two-level system (TLS) and optical degrees of freedom is typically restricted to the weak-coupling regime. By realizing the model with a nanomechanical oscillator coupled to a (double) quantum dot, the accessible parameter space changes significantly (1). We study such a hybrid mechanical–electronic system in which the oscillator frequency is much smaller than the TLS energy splitting, while the coupling strength is comparable to the oscillator frequency, thereby entering the ultra-strong coupling regime. Experimentally, the system can be driven through the TLS and probed via an additional, weakly coupled microwave cavity that acts as a readout device. This setup has been demonstrated in the group of Bachtold (2). Our theoretical analysis concentrates on the parameter regime characteristic of these experiments and of ongoing work within the same group. We present an analysis of both the intrinsic behavior of the system and the experimentally accessible signal, ranging from a closed-system quantum description to a semiclassical open-system treatment. In the fully quantum case, the model yields an effective nonlinear Kerr term for the oscillator. In the semiclassical regime, we show that adiabatic elimination of the TLS leads to a nonlinear Duffing-type oscillator, coupled to the cavity in a nontrivial way. This coupling enables characterization of the mechanical oscillator via cavity measurements. While both the mechanical oscillator and the cavity feature long lifetimes, the TLS may suffer from comparatively strong decoherence and decay. Depending on these rates, retardation effects can modify the effective equations of motion of the reduced system, introducing additional dissipation channels for the oscillator.

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*Speaker

Observation of strong tripartite coupling in a cavity-quantum circuit-antiferromagnet platform

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The hybridization of quantum states hosted by materials of very different nature is a resource for quantum technologies. A major example is the light matter interaction which is now at the heart of many quantum computing architectures. In some instances, it is crucial to interface coherently more than two quantum systems, as needed for frequency conversion for example. Such enhanced multipartite quantum blocks have long been envisioned in the field of magnonics, but the observation of coherent interaction of more than 2 systems has remained an outstanding challenge so far. Here, by combining an antiferromagnetic crystal, a magnetic field resilient superconducting circuit and a microwave cavity, we demonstrate that we can produce strongly hybridized light-superconducting circuit-magnon states. The anharmonicity of the superconducting circuit enables efficient frequency conversion between all the 3 modes. As antiferromagnets are naturally suited for coupling to THz signals, our work gives a path for quantum interfaces between microwave and THz radiations.

*Speaker

Measurement Induced State Transitions and TLS lifetime signatures

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Achieving high-fidelity measurement in superconducting qubits is essential for scalable quantum computing but remains limited by measurement-induced transitions, or qubit ionization, that occur at specific photon populations in the readout resonator. By explicitly controlling and calibrating the offset charge of a transmon qubit, we experimentally reveal the gate-charge dependence of these transitions-even deep in the transmon regime-thus providing new insight into how higher-order excitations and Hamiltonian corrections shape measurement backaction. Building on these improved measurement strategies, we extend our approach to probe the qubit's microscopic environment. Through wideband spectroscopy and correlation analysis, we identify long-lived two-level systems (TLS) coupled to the qubit and perform Stark-shift pump–probe experiments to directly measure their intrinsic lifetimes. Together, these results show how refined understanding and mitigation of measurement-induced effects open the way to resolving and characterizing individual TLS defects that limit qubit coherence.

*Speaker

Probing the quantum motion of a macroscopic mechanical oscillator with a radio-frequency superconducting qubit

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Long-lived mechanical resonators like drums oscillating at MHz frequencies and operating in the quantum regime offer a powerful platform for quantum technologies and tests of fundamental physics (1).

Yet, quantum control of such systems remains challenging, particularly owing to their low energy scale and the difficulty of achieving efficient coupling to other well-controlled quantum devices.

Here, we demonstrate repeated, and high-fidelity interactions between a 4 MHz suspended silicon nitride membrane and a resonant superconducting heavy-fluxonium qubit (2-4), representing, to our knowledge, the first realization of resonant coupling in such a hybrid system at record-low frequencies.

The qubit is initialized at an effective temperature of 21 μK and read out with 77 % single-shot fidelity.

During the 6_˜ms lifetime of the membrane the two systems swap excitations more than 300 times.

After each interaction, a

state-selective detection is performed, implementing a stroboscopic series of weak measurements that provide information about the mechanical state.

The accumulated records reconstruct the position noise-spectrum of the membrane, revealing both its thermal occupation n_th _˜ 47$ at 10 mK and the qubit-induced back-action.

By preparing the qubit either in its ground or excited state before each interaction, we observe an imbalance between the emission and absorption spectra, proportional to n_th and n_th

*Speaker

+ 1 respectively, a hallmark of the non-commutation of phonon creation and annihilation operators.

Since the predicted Diósi–Penrose gravitational collapse time (5-6) is comparable to the measured mechanical decoherence time, our architecture enters a regime where gravity-induced decoherence could be tested directly (7).

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Altermagnetic Anomalous Hall Effect Emerging from Electronic Correlations

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While altermagnetic materials are characterized by a vanishing net magnetic moment, their symmetry in principle allows for the existence of an anomalous Hall effect. Here, we introduce a model with altermagnetism in which the emergence of an anomalous Hall effect is driven by interactions. This model is grounded in a modified Kane-Mele framework with antiferromagnetic spin-spin correlations. Quantum Monte Carlo simulations show that the system undergoes a finite temperature phase transition governed by a primary antiferromagnetic order parameter accompanied by a secondary one of Haldane type. The emergence of both orders turns the metallic state of the system, away from half-filling, to an altermagnet with a finite anomalous Hall conductivity. A mean field ansatz corroborates these results, which pave the way into the study of correlation induced altermagnets with finite Berry curvature.

*Speaker

State-of-the-art in Circuit Quantum Electrodynamics

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Last October, Michel Devoret, John Clarke and John Martinis were awarded the Physics Nobel Prize for the first demonstration of macroscopic quantum phenomena in a superconducting circuit. Four decades after their seminal experiment, many academic labs and companies worldwide engineer superconducting circuits to explore all facets of quantum mechanics from its foundations to its applications in sensing or computing. This tutorial will present what is the present state of research on the superconducting circuit version of Cavity Quantum Electrodynamics. Starting from the basics of the field, including a mention of the experiments awarded by the Physics Nobel Prize in 2025, the tutorial will discuss recently solved problems and current challenges.

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Parametric drive of a double quantum dot in a cavity

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Fast and high-fidelity qubit readout remains a central challenge in quantum technologies. In cavity quantum electrodynamics (cQED), the conventional "transverse" coupling between a qubit and the cavity provides state-dependent frequency shifts but suffers from a trade-off: increasing the measurement signal also enhances qubit dephasing. A promising alternative is the "longitudinal" readout scheme, where a parametric modulation of the longitudinal coupling at the cavity frequency produces a cavity-field displacement directly conditioned on the qubit state, allowing faster and potentially quantum non-demolition readout (1).

Double quantum dots (DQDs) coupled to microwave resonators naturally exhibit both transverse and longitudinal coupling components. Because of this coupling structure, modulating the dipole with an external microwave drive seems an intuitive route to realize longitudinal readout (2,3). We have implemented this approach using a suspended carbon-nanotube DQD coupled to a superconducting coplanar waveguide resonator. By applying a parametric gate drive at the cavity frequency and precisely tuning the relative phase and amplitude of the cavity and gate excitations, we identify the physical origin of the observed signal. Our measurements show unambiguously that the cavity response does not result from a true longitudinal coupling but from dipole radiation emitted by the parametrically driven DQD-an effect still governed by transverse coupling (4). Despite this, the new readout mechanism can be tuned to achieve a π-phase shift between dipole states, yielding a strong enhancement of the signal-to-noise ratio. This dynamic modulation technique also offers a powerful probe for exotic quantum states in hybrid mesoscopic circuits.

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Synchronous motion of Abrikosov vortices: one, two... many

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Transport properties in current-biased superconducting nano-bridges is determined by the motion of the quantum vortex confined in the disorder landscape. Depending on the geometry of the bridge, it can be a motion of several vortices or thousands of them. Their mutual interaction and interaction with the disordered landscape lead to a rich phase diagram of transport properties.
We consider both theoretically and experimentally a specific subdomain of this diagram, where vortices are synchronized with an external periodic drive. It contains numerous peculiarities in current-voltage characteristics such as fractional Shapiro steps due to strong anharmonicity of the vortex motion locked to the radio frequency (RF) excitation or negative dynamic resistance (NDR), characterized by metastable states that can be RF-drive (1). Starting from models for two vortices, we then consider behaviour of thousands of them in experiments with high-temperature (HTc) superconductors, showing the rigidity of effects (2-3).

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*Speaker

Electrostatically defined graphene quantum dots

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Graphene is a promising candidate for future nano-electronic devices including building blocks for quantum information processing. Reasons are the expected long spin lifetimes and high carrier mobility. The improvements in fabrication technologies for graphene nanostructures, namely, the encapsulation between boron nitride, edge-contacting, graphite back-gates and the use of electrostatic gating of bilayer graphene, have leveraged the quality of quantum dots to such an extent, that few-electron or -hole quantum dots have been realized that are comparable to the best devices in gallium arsenide (1).
We confine charge carriers laterally by applying strong displacement fields forcing charge carriers to flow through a narrow channel. In transport direction, charge carriers are confined by pn-junctions forming natural tunnel barriers, thus creating a p-type quantum dot coupled to n-type leads, or vice versa. The tunnel barriers can be tuned using additional gates, providing a high degree of control through gate voltage over the quantum dots' charge, spin, and valley degrees of freedom.

Our experimental findings yield a notably clear level scheme for two-particle spectra. Intriguingly, the single-dot two-carrier ground state of bilayer graphene quantum dots is not a paired spin-singlet, but a spin-triplet (2). This discovery holds significant implications for the design of typical two-carrier singlet-triplet qubits. Through the implementation of charge detection, we have successfully performed Elzerman read-out (3) and measured single-spin relaxation times (T1) up to 50ms. Recent observations indicate extended valley T1 relaxation times, approaching 1s, between the spin (valley) (1,1) triplet and (0,2) singlet states in a double quantum dot (4).

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*Speaker

crystal field and anomalous gating in bilayer graphene/hBN heterostructures

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Recent reports have shown that van der Waals heterostructures based on bilayer graphene encapsulated between hexagonal boron nitride (BN) flakes develop signatures of anomalous gating when placed under a perpendicular electric field (1), (2). The fingerprints of this phenomenon are gate ineffectiveness regions and hysteresis of transport signatures between backward and forward directions of the gate voltage application.
This unexpected behaviour has been attributed to the emergence of a ferroelectric state, based on the formation of a moiré superlattice between graphene and BN and the presence of electronic correlations. However, the precise mechanism giving rise to this phenomenon remains unclear.

Here we present results on a novel device architecture (3), dynamically rotatable dual-gated heterostructures, which allows us to probe the charge transport properties of the material while combining the application of a displacement field with dynamical control of the relative angle between the layers of the system.

We characterize a range of $\pm 15\circ$ around the $30\circ$ position where we identify three distinct regimes of behavior as a function of angular misalignment. Outside of this range we are able to recover the standard, well-documented performance of bilayer graphene under a displacement field (4).

Hall density measurements performed at low temperature complete the picture showing the electronic ratchet effect (5), further confirming that this behaviour is independent from the moiré effect between graphene and BN.

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*Speaker

Time-resolved sensing of electromagnetic fields with single-electron interferometry

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The quantum coherence of single electronic states in mesoscopic system is usually very fragile. This fragility can be harnessed to create hyper-sensitive quantum sensors such that a single electron can detect a few photons excitation. In this work, we demonstrate a quantum sensor that exploits the variations of the phase of a single electron wavefunction upon its interaction with a classical time-dependent electric field. We use a Fabry-Perot interferometer in the quantum Hall regime to extract the phase of the wave packet as a function of time. Such device ensures a fast and sensitive detection as are able to detect a signal equivalent to a few microwave photons with a resolution of 50 ps. Moreover, by measuring both the phase and contrast of the interferometer, it is possible to obtain information on both the amplitude of the electromagnetic field and its fluctuations. This opens possibilities for on-chip detection of non-classical radiation such as squeezed states or Fock states. (1) Bartolomei, Hugo, et al. "Time-resolved sensing of electromagnetic fields with single-electron interferometry." arXiv preprint arXiv:2408.12903 (2024).

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Tensor networks toolbox for quantum systems

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This tutorial will present a general and brief introduction to tensor networks, with an emphasis on matrix product states (MPS) and their various applications to the field of mesoscopic quantum systems. Historically, MPS (namely DMRG) has been the main approach to simulate one-dimensional interacting quantum systems. Interestingly, MPS have emerged recently as a more general language for processing quantum data, or for applications far beyond the historical ones, giving rise to the so-called quantum inspired algorithms. Many modern libraries are user-friendly and reliable, offering a new toolbox for theoreticians and experimentalists in the field.

*Speaker

A nanoscale Cooper pair diode

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Superconducting diodes, devices that allow Cooper pair currents to flow more easily in one direction than the other, are set to become key building blocks for dissipationless electronics. Existing realizations, however, rely on magnetic fields, ferromagnets, or complex heterostructures that hinder integration and scalability. Here we demonstrate a diode effect for Cooper pairs that arises solely from electron–electron interactions in nanoscale superconducting islands. When these lead islands are driven into the Coulomb blockade regime, Cooper pair transport occurs through resonant charge states. By tuning the island's electrostatic environment, we controllably break particle–hole symmetry and induce nonreciprocal supercurrents, thereby achieving a gate-switchable Josephson diode without any external magnetic field. Our approach enables robust rectification of superconducting currents and microwave photoresponse, providing a scalable strategy to superconducting logic devices.

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Experimental evidence for a fractional entropy in the two- and three-channel Kondo states

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Unconventional quantum states defying the widespread Fermi quasiparticle paradigm are predicted to emerge in the presence of strong electronic correlations. Among them, Majorana and Fibonacci excitations are especially promising for topological quantum information, yet notoriously difficult to identify unambiguously. The entropy was proposed as a discerning observable, with fractional ground state values (half kB ln(2) for a Majorana) involving non-local correlations and relating to their non-Abelian character. In this talk, I will present how we managed to demonstrate the fractional nature of the entropy of such states. Using a metal–semiconductor nanocircuit engineered to realize two- and three-channel Kondo effects, we extract the impurity entropy via Maxwell relations from charge measurements of a metallic island. Our results reveal universal flows to fractional plateaus at low temperatures consistent with the predictions of a free Majorana and of a Fibonacci anyon for, respectively, the two- and three-channel Kondo states. These findings establish the entropy as a powerful probe of engineered nanocircuits and pinpoint the emergence of exotic quantum states with quantum information potentialities.

*Speaker

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Dissipation-engineering with a dc-biased Josephson junction

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Superconducting circuits coupled to voltage-biased quantum conductors are a promising platform for the manipulation of microwave light at the quantum level. Photons can be created or exchanged between different modes of the circuit, mediated by the inelastic tunneling of charges through the conductor. This mechanism allows for the creation of bright sources of quantum microwaves, quantum-limited amplification and photon-number multiplication, as well as dissipation engineering.
In these experiments, dissipation engineering is achieved by coupling a resonator to a dissipative environment through a multi-photon exchange process, such that the resonator effectively loses pairs -or triplets- of photons. This mechanism has been investigated so far either by detecting the photons lost to the bath, or by direct spectroscopy of the resonator.
We present a new experiment where we have measured directly the quantum state of a high-quality factor resonator losing pairs of photons through inelastic-Cooper pair tunneling. We perform the Wigner tomography of this quantum memory using a transmon qubit, and study the impact of two-photon losses on the dynamics of the resonator. These results pave the way towards using this new form of dissipation engineering to stabilize an error-corrected cat-qubit.

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SUPERCONDUCTING QUBITS AND AMPLIFIERS RESILIENT TO TESLA-SCALE MAGNETIC FIELDS

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Superconducting qubits with quantum non-demolition readout and active feedback can act as information engines to probe and control microscopic degrees of freedom, both engineered and environmental. However, the magnetic field bias poses a significant challenge for the operation of conventional qubits. We demonstrate a fluxonium qubit with a granular aluminum nanojunction (gralmonium) that maintains spectral stability and coherence above 1 T (arxiv.org/abs/2501.03661). This robust performance enables exploration of spin environment dynamics and supports hybrid quantum architectures integrating superconducting qubits with spin systems.

*Speaker

Topological order at finite temperature in string-net models

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Topological order is a special type of quantum order that arises in strongly interacting, gapped quantum systems. In two-dimensional systems at zero temperature, it is characterized by a ground-state degeneracy that depends on the topology of the system (for instance, whether it is placed on a sphere or a torus) and by the presence of exotic quasiparticles with fractional exchange statistics, called anyons. These properties are well-known to be stable against small local perturbations at zero temperature and make topologically-ordered systems promising candidates for fault-tolerant quantum computation. However, they may be fragile in the presence of thermal fluctuations.
In this talk, I will discuss how thermal fluctuations affect topological order in the Levin-Wen string-net models, exactly solvable models that capture a broad class of topologically-ordered phases. First, I will present how the degeneracies of all excited energy levels and the partition function of these models can be obtained analytically. From the partition function, we can then show that topological order is lost at any nonzero temperature in the thermodynamic limit. For finite system size L, however, the main characteristics of topological order are preserved below a size-dependent temperature scaling as 1/logL. These results are particularly relevant given the recent progress in simulating string-net models using quantum artificial devices.

A. Ritz-Zwilling, J.-N. Fuchs, S. H. Simon, J. Vidal, Phys. Rev. B 109, 045130 (2024) and Phys. Rev. B 110, 155147 (2024)

*Speaker

Absence of Charge Offset Drift in a Transmon Qubit

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The electric environment of mesoscopic devices is noisy. The dynamics of that noise and its impact on a Cooper pair box is entirely captured by a single parameter: the equilibrium number of Cooper pairs on the island, called the charge offset. The transmon qubit, a Cooper pair box with a large capacitance, is designed to be insensitive to charge offset noise. Yet the qubit readout speed depends on this charge offset and the noise also limits the coherence of protected qubits based on junction arrays.

Many experiments have used Cooper pair boxes to probe the dynamics of the charge offset, and all have observed that it drifts with timescales of minutes to hours. I will present an experiment on a transmon qubit, where we observed the charge offset to be zero in all the measurements we performed over the course of 85 days and a thermal cycle.

We attribute this cancellation of the charge offset to the presence of a highly resistive thin film of tantalum in parallel to the Josephson junction, that we observe with X-ray Photoelectron Spectroscopy and Energy Dispersive X-Ray Spectroscopy. Remarkably, this film is so resistive that it does not limit the transmon relaxation and coherence times, nor the tunneling of quasiparticles in and out of the transmon island.

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Chern junctions in Moiré-Patterned Graphene/PbI2

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Expanding the moir'e material library continues to unlock novel quantum phases and emergent
electronic behaviors. In this work, we introduce PbI2 into the moir'e family and investigate the magnetotransport properties of moir'e superlattice in a hexagonal boron nitride/graphene/PbI2 heterostructures.
In high-field quantum Hall regime, we observe a robust dissipationless transport at
charge neutrality point, indicative of incompressible states stabilized at the filling factor h = 0. Additionally, a fractional conductance plateau at 2/3 e2/h emerges, which we attribute to a Chern
junction between domains with distinct Chern numbers originating from moir'e-modulated and conventional
integer quantum Hall states. The moir'e Hofstadter spectrum displays an unconventional
flavor sequence, likely influenced by proximity-induced spin–orbit coupling from the PbI2 layer. We
also see coherent electronic interference along lines with Chern number m = -2. These findings position PbI2-based heterostructures as a versatile platform for realizing spin–orbit-enhanced moir'e
phenomena and engineering coherent edge transport in two-dimensional quantum materials.

*Speaker

Time-domain braiding of anyons can be revealed through novel nonequilibrium fluctuation–dissipation relations

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Two-dimensional systems can host exotic quasiparticles known as anyons, which exhibit fractional charge and exchange statistics beyond the boson–fermion dichotomy. Recent interferometric and cross correlation setups have provided major advances in detecting anyonic braiding (1-4), though they remain limited by Coulomb coupling, nonuniversal effects, and ambiguities in extracting the braiding phase (5,6).

We derive a nonequilibrium fluctuation–dissipation theorem (FDT) that directly encodes anyonic braiding in the time domain (7). Our derivation, based on the Unifying Nonequilibrium Perturbative Theory (UNEPT) (8,9), applies to standard reservoir geometries as well as configurations with one or two quantum point contacts (QPCs) injecting dilute anyonic fluxes. The resulting braiding FDT leads to two complementary schemes to determine the braiding phase in the time domain: (i) from the relation between DC noise and the integrated current under DC bias, and (ii) from the connection between the AC current phase shift and the DC noise. The latter provides a robust and self-calibrating probe of the statistical angle
theta, resilient to nonuniversal renormalization.

For a thermalized Tomonaga–Luttinger liquid (TLL), we show that in the quantum regime the phase shift of AC current directly yields the scaling dimension δ for $\delta > 1/2$. These results establish experimentally accessible routes to extract
theta or δ in minimal single-QPC setups, without relying on interferometry or cross-correlation techniques.

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Single-shot experiments with flying electrons

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Thanks to the experimental advances of the last years, quantum transport in electronic devices can now be studied using individual electrons instead of a continuous flow. This technical breakthrough marks a significant shift in the field of mesoscopic quantum physics, as it allows the exploration of effects previously restricted to quantum optics. To emphasize the similarity, this new field of research is called electron quantum optics. In particular, experiments in both domains share the same requirement for a ballistic transport of the particles, as well as elements controlling their transmission and polarization. While these conditions have long been met thanks to the existence of high-mobility two-dimensional electron gases in heterostructures of semiconductors or encapsulated graphene, there are two other essential ingredients for conducting electron quantum optics experiments: single-electron sources and single-electron detectors. Although several sources of individual electrons are now available, their individual detection remains a major challenge in the field.
In this presentation, I will discuss a few platforms that already enable this single-particle detection (1,2) and explain how they allow the analysis of particle collision experiments to identify correlations between them. Unlike other platforms that require a repeated particle delivery to measure correlations through current-noise measurements, platforms with single-particle detection provide direct access to the full counting statistics, thus revealing correlations beyond the second order. To illustrate this major advantage, I will present our recent results on the partitioning of a quantum dot containing up to 5 electrons transported by a surface acoustic wave in the piezoelectric GaAs semiconductor (3). In particular, the use of a statistical tool called cumulant makes it possible to directly highlight correlations up to the fifth order. Moreover, the introduction of an effective Ising model enables to characterize the degree of correlation within the electron droplet, revealing a Coulomb liquid-like behavior.

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*Speaker

Andreev spin qubit protected by Franck-Condon blockade

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Andreev levels localized in a weak link between two superconductors can trap a superconducting quasiparticle. If there is a spin-orbit coupling in the link, the spin of the quasiparticle couples to the Josephson current. This effect can be leveraged to control and readout the spin of the quasiparticle thus using it as a qubit. One of the factors limiting the performance of such an Andreev spin qubit is spin relaxation. Here, we theoretically demonstrate that the relaxation lifetime can be enhanced by utilizing the coupling between the Andreev spin and the supercurrent in a transmon circuit. The coupling ensures that the flip of the quasiparticle spin can only happen if it is accompanied by the excitation of multiple plasmons, as dictated by the Frank-Condon principle. This blocks spin relaxation at temperatures small compared to plasmon energy.

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Nearly optimal microwave-to-acoustic piezoelectric transduction using SQUID arrays

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Acoustic waves play an essential role in various classical and quantum systems, such as microwave-to-optics transducers, quantum acoustic devices, and devices that use strain to couple to spin defects. Central to these experiments is the transducer, which enables the exchange of signals between electrical and acoustic networks. This transduction is commonly achieved by exploiting piezoelectricity. However, conventional piezoelectric transducers are limited to either small efficiencies or narrow bandwidths and typically operate at fixed frequencies. These limitations restrict their utility in many applications.

We propose and demonstrate an effective method for achieving piezoelectric microwave-acoustic transduction that approaches the maximum efficiency-bandwidth permitted by the piezoelectric coupling constant of lithium niobate (1). We use SQUID arrays to impedance-match the large complex impedance of wide-band interdigital transducers that excite Lamb waves in suspended lithium niobate. We demonstrate unprecedented efficiency x bandwidth of 440 MHz, with a maximum efficiency of 62% at 5.7 GHz. Moreover, leveraging the flux dependence of SQUIDs, we realize transducers with in-situ tunability across the 4-7 GHz band.

Our transducer is compatible with the quantum toolbox of superconducting circuits and it can be connected directly to parametric amplifiers, microwave photon counters, etc. We envision applications in microwave-to-optics conversion schemes, acoustic spectroscopy in the 4-8 GHz band, or quantum-limited phonon detection.

(1) arXiv.2501.09661 (to appear in Nature Electronics)

*Speaker

Hybrid circuits with van-der-Waals superconductors

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Superconducting circuits are quantum devices that mimic the behavior of atomic systems even though they are made up of macroscopic microwave circuit elements. Their tunability, high coherence, and strong coupling has led to their rapid development as a leading implementation of quantum hardware. Traditional circuits are made using known superconductors such as aluminum or niobium, but the integration of novel superconductors as part of the circuit can lead to new scientific insights and new capabilities. Such hybrid circuits are especially useful for exploring superconductivity in van-der-Waals flakes and heterostructures, whose microscopic size prevents many of the standard characterization methods used for bulk materials. Furthermore, the unique quantum properties of unconventional superconductors can be utilized to make a new class of protected quantum devices. This talk will present recent results where we explore novel superconductors with hybrid circuits, and a path towards utilizing them in new hybrid devices for quantum technology.

*Speaker