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Oral presentations

Superconductor/Semiconductor Heterostructures for Quantum Computing Applications

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TBA

*Speaker

EuS Interfaces for Superconducting Spintronics

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Magnetic insulators (MI) carry magnetic moment without charge dissipation, which is beneficial for both spintronic and proximity effect-mediated superconductor engineering, especially at cryogenic temperatures. Yet, few MI compounds can be deposited as thin films on top of Si/SiOx substrates and then processed with typical lithography methods. EuS is a MI compound which display stable and reproducible magnetization properties even when grown with polycrystalline structure. Thus, the use of EuS interfaces in low temperature spintronic and superconducting devices seems promising. First, I will present a characterization of the magnonic properties of EuS films at low temperature (2K). In devices comprising heavy metal/EuS interfaces, we observe that spin signals can be injected and propagate through the EuS films by the spin Seebeck effect. Moreover, ferromagnetic resonance measurements of the EuS films reveal a Gilbert damping of 10-3 at 2K in polycrystalline films, pointing to the possibility of exploiting EuS interfaces for coherent low temperature magnonics (1). Finally, I will illustrate the introduction of EuS/Al electrodes in vertical EuS/Al/AlOx/Al Josephson junctions. The proximity effect induces a sharp spin-splitting of the density of states of the Al electrode in contact with the EuS film, clearly observed in the tunnelling spectroscopy of the junctions (2). At the same time, we observe that the superconducting gap is well defined for reasonable temperature and in-plane magnetic field ranges. The I-V characteristics of the more transparent junctions reveal the presence of in-gap superconducting transport processes, such as the Josephson effect and multiple Andreev reflections. Fittings of the dI/dV of the junctions demonstrate how the EuS interfacial exchange field affects such processes.

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*Speaker

Optimising the superconductor-semiconductor interface in all-Si devices

Léonard Desvignes [1], Aiken Van Waveren [1], Géraldine Hallais [1], D. Débarre [1], Alberto Debernardi [2], Michele Amato [3], Bernard Sermage [4], Francesca Chiodi * [1]

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Since the discovery of BCS superconductivity in silicon by nanosecond laser ultra-doping with boron, theoretical and experimental works have endeavored to understand what triggers and controls the superconducting phase. Indeed, superconducting Si has great potential to develop a cryogenic electronics with the advantages of large scale integration and high reproducibility. Through the optimization of the nanosecond laser temporal profile, we achieved an excellent control of both the electrical and structural properties of ultra-doped Si thin layers, with a maximum carrier concentration of 8 at.%, the state of the art, in monocrystalline epilayers with few defects, 100% dopant activation up to and above the solubility limit, and a vertically homogeneous doping profile (1-3).
The control and improvement of the active doping is directly reflected in the control of the superconducting critical temperature Tc of such disordered superconductor, increased by 30% in this optimized setup, in agreement with theory and opposite to previous results (Fig.1) (2).

Furthermore, we demonstrated that superconductivity is not only controlled by doping, but also by the lattice deformation. Thus, it is possible to tune up to 50% Tc by modifying by 1% the lattice parameter, as shown through nanosecond laser incorporation of Ge up to 20 at.% (4).

Mastering and understanding the materials properties has brought to the development of all-silicon devices, such as Josephson junctions and superconducting microwave resonators (5).

Indeed, SQUIDs and Josephson junctions were developed (6), thanks to the excellent, epitaxial, transparent interface between superconducting Si and semiconducting Si, that we have characterized both at room temperature and at sub-K temperatures as a function of the semiconductor doping.

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Spin-orbit induced spontaneous supercurrent and rectification effects in 2D superconductors

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Spin-orbit interaction makes it possible to control supercurrent by acting on the spin, e.g. by a Zeeman field or exchange interaction. In 2D systems, this mechanism is at the basis of the recently discovered nonreciprocal phenomena, as e.g., anomalous Josephson effect, magnetochiral anisotropy and diode effect. In such phenomena, a spontaneous supercurrent is obtained in the presence of broken inversion and time reversal symmetry. I will present a unified picture of these phenomena discussing plain films, Abrikosov vortices, single Josephson junctions and arrays in devices with strong Rashba spin orbit interaction.

*Speaker

Biharmonic-Drive Tunable Josephson Diode (on the InAs-on-Insulator platform)

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The superconducting diode effect has garnered significant interest due to its prospective applications in cryogenic electronics and computing, enabling directional supercurrent transport. This phenomenon has been demonstrated across various superconducting platforms, including spin-orbit-based Josephson junction, van der Waals materials and interferometric devices. These devices often require peculiar materials with broken spatial symmetries or the application of magnetic field to break time reversal, making them challenging to scale and integrate into computer chips and quantum devices.
Here is shown a novel approach to realize the superconducting diode effect using a conventional Josephson junction integrated on a hybrid InAs-on-Insulator (InAsOI) platform (1)(2). Unlike previous implementations that rely on exotic materials or external magnetic fields, this method introduces a biharmonic AC drive to break space-time symmetries dynamically. By applying two harmonic signals with distinct frequencies, amplitudes, and phases, either galvanically or wirelessly via antenna, we achieve full control over the diode's polarity and efficiency, enabling ideal diode behavior (100% efficiency) with fast and contactless tunability. The hybrid InAsOI platform ensures compatibility with scalable fabrication processes and supports robust device performance up to 800 mK and across a broad frequency range, from a few Hz to several GHz.

Our experimental results demonstrate that the device can actively rectify AC signals in real time. The direction and strength of rectification are governed by the phase and amplitude ratio of the drive components, offering a versatile and programmable functionality.

The dynamically adjustable polarity of the superconducting diode could facilitate the development of fundamental logic gates and ultra-fast switches, thereby advancing superconductor-based digital electronics and the capability of this superconducting diode to function as a controllable active rectifier, essential for the conversion and management of electrical energy, paves the way for advances in superconducting integrated power electronics.

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Cavity-enhanced superconductivity via band engineering

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We consider a two-dimensional electron gas interacting with a quantized cavity mode. We find that the coupling between the electrons and the photons in the cavity enhances the superconducting gap. Crucially, all terms in the Peierls phase are kept, in contrast to more naive approaches, which may result in spurious superradiant phase transitions. We use a mean-field theory to show that the gap increases approximately linearly with the cavity coupling strength. The effect can be observed locally as an increase in the gap size via scanning-tunneling microscopy (STM) measurements for a flake of a two-dimensional (2D) material (or for a moiré system where the enhancement is expected to be more pronounced due to a large lattice constant) interacting with a locally structured electromagnetic field formed by split-ring resonators. Our results are also relevant for quantum optics setups with cold atoms interacting with the cavity mode, where the lattice geometry and system parameters can be tuned in a vast range.

*Speaker

Poster presentations

Parity-protected qubit based on Fourier engineering of the energy-phase relation

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One promising candidate for a protected superconducting qubit is the so-called cos2ϕ qubit, which employs nonlinear elements that enable coherent tunneling of Cooper pairs. This nonlinear element results in a Josephson potential containing only even harmonic terms, providing intrinsic protection against dielectric loss. In this work, we explore the realization of such a qubit using probably the simplest source of a non-sinusoidal current–phase relation (CPR): two Josephson tunnel junctions connected in series as described in Ref.(1). In this talk we demonstrate that this basic SIS–SIS configuration can exhibit an effective SNS-like CPR, supported by measurements of the qubit spectrum, and we discuss possible noise contributions within this system.

*Speaker

Andreev reflection and quantized excess current in a Bilayer Graphene Quantum Point Contact

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We present a superconducting quantum point contact (QPC) realized in bilayer graphene using electrostatic confinement and coupled to a single aluminum superconducting electrode. In the normal state, the device exhibits conductance quantization in units of 4eˆ2/h. Upon entering the superconducting state, these plateaus are systematically enhanced due to Andreev reflection at the graphene–superconductor interface. Finite-bias measurements reveal a pronounced above-gap anomaly linked to the suppression of the Andreev excess current. Current-biased measurements show that this suppression occurs at a well-defined switching current that evolves in discrete steps as individual QPC modes are opened. These results demonstrate mode-resolved Andreev transport in a proximitized one-dimensional graphene channel and establish bilayer-graphene QPCs as a promising platform for hybrid superconducting devices.

*Speaker

Full Counting Statistics in a DQD–Resonator system driven by Squeezed Light

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We study a hybrid microwave quantum device consisting of a double quantum dot (DQD) embedded in a superconducting resonator, motivated by recent experiments demonstrating zero-bias microwave-to-electron conversion. Using a theoretical description based on a Jaynes–Cummings–type Hamiltonian and a Lindblad master equation, we analyse electron transport in the presence of a non-classical squeezed microwave drive. Full counting statistics (FCS) is introduced to characterise current fluctuations and the Fano factor beyond average transport quantities. As a reference, we outline the well-established FCS of a single quantum dot and discuss how squeezing modifies the drive term in the Hamiltonian. The goal of this work is to establish a framework for predicting how squeezed input fields imprint themselves on transport noise, forming the theoretical basis for future experimental studies.

*Speaker

Autonomous resetting a qubit by means of quantum heat engine

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We expand on the setup of autonomous resetting qubit by (Ali Aamir et al. Nature Physics vol. 21, 318–323 (2025)). Replacing one of transmons with a resonator (battery) we obtain a quantum heat engine. By setting up asymmetric couplings, we show that pumping the resonator up to a dozen photons is possible within experimentally achievable parameters. The resulting state is a doughnut shape, expressing stored useful energy. We add further two transmons, and implement autonomous reset by means of the battery. We show that for some regime of parameters, faster resetting is obtained than in the original scheme of the above paper. We present experimental proposal ready to be directly implemented.

*Speaker

Electron–Phonon and Thermal Transport Engineering in Phosphorene Nanoribbons for Quantum-Calorimetric Applications

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Recent progress in cryogenic detection technology has brought bolometers close to the quantum limit, enabling energy resolution and time-scales compatible with dispersive circuit-QED architectures and single-photon calorimetry. State-of-the-art quantum-ready bolometers-based primarily on epitaxial graphene, proximity-induced normal-metal nanowires, and Josephson-based absorbers-achieve noise-equivalent powers in the tens of zeptowatt range, sub-microsecond thermal response, and strong electron–phonon decoupling at millikelvin temperatures (1). These platforms rely on ultra-low electronic heat capacities and suppressed thermal conductance to maximise sensitivity to individual microwave or terahertz photons. Despite this progress, existing devices remain limited by material constraints such as residual disorder, restricted tunability of phonon spectra, or architectural incompatibility with scalable 2D integration (2).
The results of the study conducted during the project "Study of the effect of strain on the opto-electronic parameters of phosphorene nanostructures using quantum mechanics methods"(0063/DIA/2019/48) suggest that phosphorene nanoribbons represent a promising alternative material system for next-generation quantum-ready bolometers (3). Their inherently anisotropic phonon dispersion (4), strain-tunable thermal conductance, size-dependent band gaps, and strong directional electron–phonon coupling (5) offer a rich landscape for engineering hot-electron lifetimes and thermal isolation at cryogenic temperatures. Moreover, the quasi-one-dimensional geometry of nanoribbons enables extreme suppression of heat capacity, while the layered nature of black phosphorus permits integration with heterogeneous van der Waals platforms. This theoretical study explores the feasibility of phosphorene nanoribbons as the active element of quantum-ready bolometers using first-principles and multiscale simulations. We evaluate their electronic heat capacity and phonon-limited thermal conductance, accounting for strain-induced tunability of these properties. Projected performance is compared to the best existing graphene-based and metallic-nanowire bolometers. The results outline the fundamental limits, advantages, and design strategies for realising phosphorene-based quantum calorimeters capable of detecting microwave and terahertz photons at or near the single-quantum level.

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Hybrid quantum dot devices in magic-angle twisted bilayer graphene

Alexandra Mestre-Tora * [1], Marta Perego [1], Clara Galante-Agero [1], Kenji Watanabe [2], Takashi Taniguchi [2], Thomas Ihn [1], Klaus Ensslin [1], Denisov Artem [1]

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Magic-angle twisted bilayer graphene (MATBG) has emerged as a tunable material, hosting superconducting, semiconducting and insulating phases (1,2). Combining the phases that MATBG offers, quantum devices like Josephson junctions (3,4), rings (5), and point contacts (6) have been realized.

We explore MATBG as a novel platform hosting semiconductor-superconductor quantum dot devices, where different phase combinations can be engineered within a single device. We demonstrate carrier confinement through Coulomb blockade and explore transport in two distinct regimes: a superconducting island and a quantum dot Josephson junction (S-QD-S).

In the superconducting island regime, we observe the parity effect with a complete 2e to e crossover of the carrier charge as a function of magnetic field. In the S-QD-S regime, we observe an even-odd modulation of the Andreev bound state spectrum, compatible with the formation of Yu-Shiba-Rusinov states.

Our work introduces MATBG as a new material platform for realizations of quantum dot hybrid devices combining collective electronic phases.

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*Speaker

Anomalous phase shift in ferromagnetic hybrid Josephson junctions

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We report low-temperature transport measurements in hybrid Josephson junctions comprising semiconducting InAs nanowires with partially overlapping epitaxial ferromagnetic-insulator (FI) EuS and superconducting (S) Al shells. Using a voltage-tunable SQUID geometry, we measure the current–phase relation and observe a distinct ϕ-phase shift accompanied by a magnetic-field-induced 0–π phase transition. The anomalous phase behaviour likely originates from the interplay between broken time-reversal symmetry due to the ferromagnetic EuS layer and broken inversion symmetry arising from Rashba spin–orbit coupling in the InAs nanowire. This combination generates spin-polarized supercurrents with intrinsic phase offsets in the S/FI/S junctions. In addition, we investigate how the ϕ shift evolves as we electrostatically tune the charge carriers through different gates in the SQUID. The results demonstrate a controlled interplay between superconductivity and ferromagnetism in spin-orbit coupled nanowires, a platform suited for nonreciprocal supercurrent transport and protected quantum state generation.

*Speaker

Critical temperature of ultra-thin aluminum films

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Recently, a thermally induced substitution process between aluminum and germanium has been demonstrated. This process allowed the formation of Al/Ge/Al hybrid junctions in nanowires (1). This same type of thermal substitution exists for aluminum and silicon and allows, in addition to Al/Si/Al heterojunctions, access to ultra-thin aluminum films with thicknesses around 1 nm. We measured the transport properties of these ultra-thin aluminum films. There are all superconductors and their critical temperature varies greatly with the thickness of the film.

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*Speaker

A Proximitized Quantum Dot in Germanium: A Building Block for Highly Coherent Andreev Spin Qubits

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1

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The Andreev spin qubit (ASQ) combines the advantages of semiconductor spin qubits and superconducting qubits(1)(2). It inherits the compact footprint and gate tunability of semiconductor spin qubits, while offering long-range coupling capabilities typical of superconducting qubits. Coupling between spatially separated ASQs via superconducting loops has been demonstrated in III-V semiconductor platforms(3). However, conventional readout methods based on circuit quantum electrodynamics require large resonators that hinder scalability and are difficult to implement on heterostructures without complex techniques such as flip-chip bonding. Moreover, ASQs fabricated on III-V materials suffer from magnetic field noise due to nuclear spins(4). On the other hand, spin-to-charge conversion techniques such as Pauli spin blockade-widely used in semiconductor spin qubit architectures-offer a promising route to compact ASQ readout. Germanium heterostructures present a compelling alternative to III-V materials, offering strong spin-orbit coupling, transparent superconductor-semiconductor interfaces, and the possibility of isotopic purification to eliminate nuclear spin noise(5).

Here, we present the first quantum dot in planar germanium proximitized by a superconducting lead(6). By tuning the coupling between the quantum dot and the superconducting lead, and consequently the ratio between charging energy and superconducting pair potential, we demonstrate controlled ground state transitions between singlet and doublet configurations. These transitions mark a critical prerequisite for operating Andreev spin qubits, as they enable controlled access to spin-dependent ground states. Building on this result, we aim to integrate proximitized quantum dots into superconducting loops for phase biasing, and employ adjacent quantum dots for Pauli spin blockade readout. Finally, we outline a potential layout for a scalable architecture of spin qubits in germanium that integrates both ASQs and conventional spin qubits, paving the way toward scalable quantum processors in germanium.

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Inductively Protected Andreev Spin Qubit (IPA-SQ)

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Qubits use quantum superpositions to encode and process quantum information. However, unlike conventional bits, this makes them extremely susceptible to environmental fluctuations, leading to decoherence and relaxation. This has motivated the search for protected qubits that minimize sensitivity to these perturbations, extend coherence times, and improve the scalability of quantum processors.

Here, we present a new protected-Andreev-spin qubit design based on a superconductor–semiconductor hybrid platform (1). We use a fluxonium qubit with a well-defined quantum dot Josephson junction, which leads to a spin-split doublet ground state. The addition of an inductor (EL) provides the potential landscape to tune the system into a sweet spot, gaining phase-noise protection and enabling the separation of spin states of the quantum dot into two different minima (fluxonium sweet spot), controlled by the ratio between the Josephson and inductive energies (EJ/EL).

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*Speaker

Superconducting Silicon Josephson Junctions: Reliable fabrication and supercurrent manipulation

Aiken Van Waveren * [1], Léonard Desvignes [1], Jérome Bourçois [2], Silvin Hervé [2], János Lábár [3], B. Pécz [3], David Bouville [1], Teo Baptiste [1], Alexandre Veillon [1], Paul Robin [1], Géraldine Hallais [1], Dominique Débarre [1], Francesca Chiodi [1]

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Silicon is one of the most widely-used material in electronic devices. However, it's less well-known that it is superconducting when hyperdoped with boron. Although the critical temperature is below 1 K, the compatibility with CMOS-technology makes hyperdoped silicon an interesting material to implement devices that combine not only semiconducting, metallic and superconducting Si, but also Si integrated photonic devices. To reach the active concentration necessary for superconductivity ($>$ 1 at. %), well above the equilibrium solid solubility limit, nanosecond laser doping is required, as the very fast epitaxial recrystallisation make it possible to achieve hyperdoping. One of the disadvantages of laser doping, however, is that it is difficult to spatially vary the doping below the diffraction limit associated to the nanosecond laser wavelength, λ=308 nm in our case, and thus create sub-μm devices.
For instance, the first all-silicon Josephson junctions, with lengths of the order of 100 nm, were fabricated from a superconductor (S)/doped semiconductor (sc) bilayer. The 60 nm thick S top layer was locally etched, leaving the 20 nm sc below to act as the junction's weak link. To prevent damaging the weak link underneath, the etching depth accuracy has to be below 5 nm, thus requiring precise calibration and making this step difficult to perform reliably. To get around this bottleneck, we have implemented a new method of fabricating planar SscS-junctions using masked ion implantation. The control over the doping spatial modulation is now only limited by the lateral boron diffusion during implantation and the following fast laser anneal employed to fully activate the dopants. The first results show that this method yields Josephson Junctions with a full proximity effect.
Using this promising method we are now working towards the manipulation of the supercurrent. On one hand, we have started investigating the effect of an electrostatic gate on the supercurrent. On the other, we conducted the first tests on the hyperdoping of photonics-compatible SOI. With these components we aim to create devices that can be used as building blocks to combine integrated photonics and superconductivity in one CMOS-compatible substrate.

*Speaker

Finite-temperature scaling of voltage-tuned quantum phase transitions in a hybrid Josephson-junction array

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We report transport measurements of a two-dimensional semiconductor-superconductor hybrid Josephson-junction array with a double-layer electrostatic gate, enabling independent *in situ* voltage-tuned inter-island coupling and proximity-induced superconductivity. We use this voltage to drive and study superconductor-insulator (SIT) and superconductor-metal (SMT) transitions within the same device. For each transition, we identify the critical resistivity from isotherm crossings and extract critical exponents via finite-temperature scaling. We find that the critical resistivity approaches h/4eˆ2 near the triple point, where the superconducting, metallic and insulating states meet in the gate-voltage space. Away from this point, enhancing the proximity-induced coupling increases the SIT critical resistivity while the scaling exponent remains roughly constant. In contrast, increasing the inter-island coupling systematically decreases both the SMT critical resistivity and the associated exponent. This decrease roughly coincides with a voltage-tuned crossover of the metallic state from weak localization to weak antilocalization. Based on this we discuss whether the critical behavior is sensitive to the magnitude and sign of quantum-interference corrections in the metallic regime.

*Speaker

Non-Hermitian Skin Effect and Electronic Nonlocal Transport

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Open quantum systems governed by non-Hermitian effective Hamiltonians have recently emerged as a new frontier in condensed matter physics, revealing unconventional phenomena that remain concealed in Hermitian descriptions. Among these, the non-Hermitian skin effect (NHSE), where eigenstates localize at system boundaries, has attracted intense theoretical and experimental interest in several fields, including photonics and electronic devices. However, its experimental signatures in the latter have not been described so far. In this work, we demonstrate that the NHSE naturally arises in a realistic hybrid device: a Rashba nanowire strongly coupled to a ferromagnetic lead.

We show that the NHSE can be probed through transport spectroscopy. While the local conductance remains symmetric, the non-local conductance becomes markedly non-reciprocal. We account for this behavior using both conventional transport arguments and the framework of non-Hermitian physics. Furthermore, we explain why exceptional points, points in parameter space where the effective Hamiltonian is not diagonalizable, shift in parameter space when transitioning from periodic to open boundary condition. This phenomenon has been observed in similar systems but so far not explained.

These findings establish hybrid ferromagnetic-semiconductor nanowires as a platform to explore non-Hermitian physics through transport spectroscopy.

*Speaker

Scalable Al-Ge Hybrid Heterostructures for Next-Generation Superconducting Quantum Devices

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Hybrid superconductor-semiconductor systems offer a highly promising platform for quantum information processing. We present a top-down fabrication strategy for Al-Ge-Al quantum devices on GeOI substrates, enabling scalable integration of complex superconducting circuits with atomically abrupt, oxide-free interfaces. Ge structures are defined via optical and e-beam lithography, etched with RIE, and contacted using sputtered Al followed by thermal annealing. Building on prior results from bottom-up grown Al-Ge-Al nanowires demonstrating gate-tunable supercurrents and Multiple Andreev Reflections, the top-down platform now enables systematic exploration of temperature-dependent transport in defined Ge channels. This approach supports complex device geometries and large-scale integration for advanced quantum and cryogenic nanoelectronic applications.

*Speaker

Contact resistance and junction transparency of wafer-scale CVD graphene-based Josephson field effect transistors

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The Josephson Field Effect Transistor (JoFET) is a widely pursued and desired building block for future cryogenic electronic circuits. It offers the possibility to realize analog and digital cryogenic circuits operational down to millikelvin temperatures and, thanks to its dissipationless nature, JoFET circuits can consume only a fraction of the power required by, e.g., CMOS circuits. A scalable technology to produce JoFETs is essential for the development of novel and energy-efficient superconducting electronics. Recently, we reported progress in manufacturing reproducible JoFETs using gated Al-graphene-Al junctions on wafer scale. (1)

One of the main figures of merit for inducing the superconducting proximity coupling in superconductor–semiconductor junctions is the contact resistance RC. (2) In this work, based on our wafer-scale fabrication method of graphene JoFETs further improved from previous fabrication rounds (1), we reach width-normalized RC values as low as 60 $\Omega\mu$m, with a total wafer-scale device yield of ∼98%. A gaussian fit to the RC data, as has been done throughout the process to quantify process quality, gives a distribution of $<$ RC$>$ $= 167 \pm 70$ $\Omega\mu$m, an improvement over our previous results in Ref. (1). Based on the RC values, we perform device selection and observe superconductivity of the cooled-down devicesat cryogenic temperatures. Comparing junctions of different sizes, we observe linear scaling of IC with Wg, and cover short-to-long junction regimes. For the shortest fabricated device with Lg = 50 nm and Wg = 20 μm, based on the 4-probe measurements conducted at 30 mK, we extract a normal state resistance of RN _˜ 15 Ω and critical current of IC = 7 μA. Fitting the critical current versus temperature using the Kulik-Omelyanchuk model (3), we obtain a device transparency of _˜0.4 for this device, highlighting a high-quality junction.

In conclusion, we demonstrate that our JoFET wafer-scale technology allows us to create complex cryogenic classical and quantum superconducting electronics circuits with high maturity of the process and improved performance of the devices.

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Granular Aluminum for hybrid Germanium devices

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Planar germanium quantum wells have emerged as a promising platform for superconductor-semiconductor devices. The combination of long coherence times, strong spin-orbit interaction, and robust proximity effect positions germanium uniquely for complex hybrid architectures. However, devices such as Andreev spin qubits require Zeeman splittings in the order of several GHz-a significant challenge in strained germanium quantum wells due to the small in-plane g-factors. We overcome this bottleneck by inducing superconductivity using granular aluminum (GrAl), which allows Zeeman splitting beyond 9 GHz for out-of-plane magnetic fields. We report an induced hard gap of 270 μeV and out-of-plane magnetic field resilience exceeding 200 mT using wide superconducting leads (500 nm to _˜1 μm). Remarkably, similar field resilience is obtained even for contacts up to 3 μm in width. Furthermore, by tuning the aluminum-to-oxygen ratio, we demonstrate tunability over the field resilience in the proximized germanium, providing a promising pathway to optimize superconducting properties. The use of GrAl enables a relatively simple fabrication process through room-temperature electron beam evaporation of aluminum in an oxygen atmosphere, without the need for annealing, etching, or cryogenic deposition.

*Speaker

Probing intrinsic losses of a graphene Josephson junction

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Hybrid semiconductor–superconductor quantum circuits enable new functionalities and provide access to new physical regimes for devices, such as superconducting parametric amplifiers or qubits. Among the different realizations of qubits with gate-tunable Josephson junctions, graphene-based devices have so far shown limited coherence times, in particular compared to InAs nanowires. Losses, either at the superconductor/graphene interface or intrinsic to graphene itself, might be at the origin of these limitations.

In order to gain a deeper understanding of the intrinsic properties and losses of graphene-based Josephson junctions, we perform transmission measurements on a simple device consisting of such a junction embedded in a transmission line. From this, we obtain spectra dependent on gate voltage, current bias, and input microwave power. We expect these experiments to provide an enhanced comprehension of the dissipation mechanisms of graphene-based Josephson junctions, which will help improve existing and future hybrid qubit designs.

*Speaker

Epitaxial control of group IV quantum material heterostructures

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Achieving high-quality, defect-free epitaxial interfaces between superconductor and semiconductor materials is essential to improve transparency of Josephson junctions and the robustness of superconducting qubits. To this end, integrating epitaxial Aluminum (Al) superconducting contacts grown by molecular beam epitaxy (MBE) on InAs/InGaAs QWs improved the performance of gatemon qubits (1). Exploring novel epitaxial superconductor materials is of paramount importance to enhance the quantum device performance. In this work, we will discuss the epitaxial growth of superconducting Tin (Sn) in the body-centered tetragonal β-phase (β-Sn) and the interface quality with group IV quantum materials to pave the way for their use in superconducting qubits. β-Sn has a critical temperature Tc=3.7 K that is higher than Al (Tc = 1.2 K), thus resulting in a larger superconducting gap, while also offering enhanced resilience to external magnetic fields. The use of β-Sn in superconducting quantum devices has been demonstrated with III-V semiconductors (2), however similar studies on group IV materials are still missing.

In the presentation, we will show the epitaxial growth of β-Sn on a Ge (100) wafer achieved using a cryogenic MBE system. A detailed correlation between morphology, dislocations, grain sizes, and strain of the β-Sn samples will be discussed by combining SEM, Raman, XRD, and TEM to highlight the key role of pre-growth surface engineering on the structural quality of epitaxial β-Sn. Magnetotransport measurements performed at

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*Speaker

Field-effect giant modulation of photon-mediated heat transport on the InAs-on-Insulator platform

Matteo Pioldi * [1,2], Sebastiano Battisti [1,2], Alessandro Paghi [1,2], Giorgio De Simoni [1,2], Alessandro Braggio [1,2], Lucia Sorba [1,2], Giulio Senesi [1,2], Francesco Giazotto [1,2]

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In cryogenic solid-state devices, thermal management is a crucial issue, as it prevents unwanted excitations from disrupting coherence and performance. Among various thermal management architectures, photon-mediated heat transport is an effective and versatile framework (1).
Previous works demonstrated efficient photon-mediated heat transfer between resistive metallic reservoirs linked by superconducting lines. Heat is transferred via Johnson-Nyquist black-body radiation exchanged between the reservoirs. This exchange is tuned by adjusting the impedance of components integrated into the lines. So far, this has been achieved with SQUIDs pierced by magnetic fields or Coulomb blockade on gate-controlled islands, with temperature modulations of a few millikelvins.

This study presents a novel application of photonic heat transport in super-semiconductor hybrid systems. We have developed the InAs-on-Insulator (InAsOI) platform, featuring the growth of an indium arsenide (InAs) layer on an insulating indium aluminium arsenide (InAlAs) buffer, integrated with aluminium-based superconducting electrodes (2). InAsOI enables the investigation of previously uncharacterised phenomena of heat transport in hybrid systems, effectively overcoming the limitations of entirely metallic architectures. Importantly, the InAsOI platform supports gate-tunable supercurrent densities of high magnitude, while also offering simplified and scalable configurations (2,3). Moreover, the platform demonstrates low electron-phonon thermal coupling, which is essential for achieving greater thermal isolation from the environment (4), a key requirement for larger temperature variations.

The experimental setup under study includes two InAsOI reservoirs connected via aluminium superconductive pathways, which incorporate InAsOI-Al gated weak links, specifically Josephson Field-Effect Transistors (JoFETs), along with capacitors for electrical isolation. The JoFET acts as a gate-tunable impedance, serving as an electrically controlled thermal modulator. This modulation causes temperature variations in the reservoirs exceeding 40 millikelvin, representing a tenfold improvement over previous technologies. Such precise control over the thermal dynamics of cryogenic systems demonstrates robustness across a broad range of electronic and environmental temperatures. The results highlight the potential of the hybrid InAsOI platform

*Speaker

in advancing the understanding of photonic heat transport, utilizing the superior thermal properties of semiconductors while exploring interactions with unique hybrid platform features, such as gate-tunable superconductivity. Ongoing progress in this technology is expected to facilitate effective non-galvanic and low-disturbance management of thermal flux in mesoscopic solid-state systems.

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Shapiro spectrocopy of Josephson elements

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Hybrid platforms have emerged as excellent candidates for exploring emergent quantum phenomena arising from the intricate interplay between superconductivity and the tunability of semiconductors(1). In contrast to conventional SIS junctions, SNS junctions offer an additional degree of control through gate tunability of the normal region, making them ideal systems for studying the fundamental physics of proximity-induced superconductivity and enabling applications such as Andreev spin qubits(2), gate-tunable transmon(3), SQUIDs(4), Andreev crystals(5), and more. High-transparency SNS junctions exhibit current–phase relations (CPRs) with substantial higher-harmonic content. We use top contact on ultra-shallow Ge quantum wells to realize such gate-tunable JJs(3, 4).

In such hybrid SNS junctions-and more exotic analogs like STIS junctions(6, 7)-Shapiro spectroscopy serves as a powerful experimental technique for probing the CPR. The appearance or absence of certain integer or fractional Shapiro steps in the slow-driving regime (2eI_C R $>>$ hf) is often used to infer the harmonic content of these devices. However, this approach is frequently complicated by the sensitive dependence of experimental signatures on quasiparticle poisoning, heating, and other effects that make data interpretation challenging(6, 8, 9). Additionally, extracting the relative size of their harmonics remains a challenge, and usually an additional JJ in parallel is needed to perform DC SQUID spectroscopy.

In this work, we experimentally demonstrate a novel Shapiro spectroscopy technique, measuring the response of a Josephson element in the fast driving regime (2eI_C R $<<$ hf). The technique allows for the extraction of the full harmonic content of the CPR of a Josephson element. This is done using the shape of the critical current boundary of the zero-resistance domain in the presence of an RF drive (10). We experimentally verify this by performing the spectroscopy of a balanced SQUID, where the harmonic content is flux tunable. We exploit this tunability to perform the experiment with a predominantly $\sin(2\phi)$ CPR at half flux quantum, versus away from half flux quantum, where it is predominantly $\sin(\phi)$ CPR. With this, we show a stark difference in the Shapiro spectra of the driven SQUID in the two configurations, extracting the harmonic content for each case. This experiment establishes the proposed technique as a powerful complement to existing methods for probing the CPRs of Josephson elements(11, 12).
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Behavioral and Physics-Based Modeling of Josephson Field-Effect Transistors (JoFETs)

Shanuka Gamaethige * [1], Markus Lehtisalo [2], Kari Stadius [1], Heorhii Bohuslavsky [2], Klaara Viisanen [2], Jussi Ryynänen [1], Andrey Generalov [2]

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The Josephson Field Effect Transistor (JoFET) is a versatile building block for ultra-low-power and high-energy-efficiency classical and quantum electronics. In a JoFET, the superconducting current is controlled by electrostatic gate voltage. Among various material platforms, graphene-channel JoFETs have emerged as promising candidates for superconducting hybrid integration owing to their gate-tunable transport properties (1), (2) and compatibility with scalable device fabrication (3).
Accurate modeling of JoFETs is essential for circuit-level design and understanding the physical mechanisms governing device operation (4). Here, we report two complementary modeling approaches for a graphene channel JoFET with dimensions of channel width 20 μm and length 350 nm. These models have been implemented in commercial and open-source circuit simulators, namely Keysight ADS and Ngspice.

1. Behavioral Model

The behavioral model provides a compact empirical description of the nonlinear current–voltage (I–V) characteristics by representing the gate-dependent superconducting region through a simple power-law relation. This simple empirical relation effectively reproduces the nonlinear I–V behavior observed experimentally, providing a compact lookup table-based representation of JoFET characteristics.

2. Physics-Based Model

The physics-based model links JoFET behavior to the electronic transport in the graphene channel, capturing the gate-voltage (V_g) dependence of both normal-state resistance (R_N) and critical current (I_C). It accounts for carrier density modulation in the graphene channel, including contributions from residual doping and quantum capacitance.

The superconducting critical current can be connected to the normal-state resistance through a modified Ambegaokar–Baratoff relation, reflecting the effects of junction transparency and the induced superconducting gap.

Finally, to reproduce the I–V characteristics of the device, the model is embedded within a

*Speaker

gate-dependent resistively and capacitively shunted junction (RCSJ) framework. This allowed reproducing the full I–V behavior across gate voltages, matching experimental data with high fidelity.

Overall, the combined behavioral and physics-based models comprehensively describe the JoFET's gate-tunable superconducting transport, providing deeper insight into device operation and paving the way for the development of a practical compact model.

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Diffusive versus ballistic Little-Parks effect in superconducting rings and cylinders

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A thin superconducting ring or cylinder threaded by a magnetic flux exhibits a periodic modulation of its superconducting properties, known as the Little–Parks effect, typically with a flux quantum periodicity of Φ0. In this work, we study the emergence of an even–odd modulation in this effect, corresponding to an effective 2Φ0 periodicity, and examine how it compares between the diffusive and ballistic limits. In the diffusive regime, we compute the self-consistent complex order parameter using the nonuniform, arbitrary-temperature Usadel theory, formulated as the minimization of a grand-canonical functional over quasiclassical Gor'kov Green's functions. In the ballistic limit, we obtain a fully self-consistent Hartree–Fock–Bogoliubov solution through fixed-point iteration of the mean-field equations. The comparison between these two complementary frameworks reveals the role of nonlocal Green's function components and level quantization in producing the even–odd Little–Parks effect in ring and cylindrical geometries. (Work in progress.)

*Speaker

Optimizing one dimensional superconducting diodes: Interplay of Rashba spin-orbit coupling and magnetic fields

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The invention of diodes marked a pivotal moment in solid-state electronics, with their unidirectional current flow becoming a cornerstone of semiconductor technology. This concept of non-reciprocal current flow has now found its way into superconductivity, manifesting as the Superconducting Diode Effect (SDE). As non-dissipative circuit elements, superconducting diodes can unlock potentially revolutionary applications in quantum electronics, superconducting spintronics, and quantum information technology, ranging from high-quality rectifiers to advanced microwave sensors. SDE is characterized by the directional dependence of the depairing current-the critical threshold current at which a superconductor transitions to a normal metallic state. In this work, we investigate the SDE in helical superconductors that simultaneously break inversion and time-reversal symmetries, focusing on a prototypical Rashba nanowire proximitized by an s-wave superconductor and subjected to external magnetic fields. Using a self-consistent Bogoliubov–de Gennes mean-field formalism, we explore the intricate interplay between linear and higher-order spin–orbit coupling (SOC), supercurrent flow, and Zeeman fields. Our results demonstrate that Rashba nanowires with only linear SOC can achieve incredibly large diode efficiency 45% through the interplay of longitudinal and transverse magnetic fields. Notably, higher-order SOC enables finite diode efficiency even without a longitudinal Zeeman field, which can be utilized to reveal its presence and strength in nanowires. We present a comprehensive phase diagram of the device elucidating the emergent Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) superconducting state and demonstrate that proximitized Rashba nanowires offer a versatile, practical platform for SDE, with potential realizations in existing material systems. These results provide crucial insights for optimizing SDE in nanoscale superconducting devices, paving the way for next-generation dissipationless quantum electronics.

*Speaker

February 3, 2026

Oral presentations

Andreev Physics in Hybrid Josephson Junctions

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The Josephson effect, which describes the coupling between two superconductors through a weak link, is the basis of several quantum devices. While it has mainly been harnessed in tunnel junctions, hybrid Josephson junctions – in which quantum conductors serve as weak links – offer a rich landscape of physics to explore. In such systems, the Josephson effect arises from the presence of Andreev bound states: fermionic states localized at the weak link, whose properties depend on the superconducting phase difference across the junction. In this two-hour tutorial, I will present this research field, introducing key theoretical concepts and highlighting experimental realizations.

*Speaker

Realization of basic types of Andreev molecules

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Topological superconductivity provides a promising platform to realize fault tolerant quantum hardware. The simplest topological superconducting system is the Kitaev-model, which is a chain of localized sites where neighboring ones are coupled by superconducting pairing and direct tunneling. Since state-of-the-art semiconducting nanostructures allows to create artificial atoms and tunnel couple them or interconnect by superconductors, the basic ingredients are available to build up artificial chains, which we call superconducting artificial molecule, or Andreev-molecule. Very recently various realizations of such chains have been reported where the sites are coupled in different ways, e.g. via superconducting vacuum, superconducting bound state, or superconducting artificial atom.
We will present experimental realization of two types of Andreev-molecule: i) the analog of H2 molecule, where two artificial atoms are tunnel coupled via a superconducting vacuum (1) and ii) the analog of H2O molecule, where two artificial atoms are coupled via a 3rd superconducting atom (2).

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*Speaker

Yu-Shiba-Rusinov states in a Hybrid Germanium Quantum Dot

Giorgio Fabris * [1], Paul Falthansl-Scheinecker [1], Devashish Shah [1], Maksim Borovkov [1], Anton Bubis [1], Dina Sokolova [1], Kevin Roux [1], Alejandro Andres Juanes [1], Stefano Calcaterra [2], Daniel Chrastina [2], Giovanni Isella [2], Georgios Katsaros [1]

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Holes in planar germanium are gaining significant interest in the field of spin qubits and hybrid semiconducting-superconducting devices due to their low effective mass, strong spin-orbit interaction, inducible superconductivity and the potential for isotopic purification. However, a key challenge lies in germanium's small in-plane g-factor, which complicates the merging of spin physics with proximity induced superconductivity and circuits. Here, we employ granular aluminum (GrAl) and report a hard induced gap in an ultra-shallow Ge quantum well, featuring a zero-conductance region of 200 μeV and BCS peaks at 270 μeV, with magnetic field resilience exceeding 200 mT in the out-of-plane direction for wide superconducting leads ranging from 500 nm to a few μm. Using this platform we proximitize a quantum dot and observe the formation of Yu-Shiba-Rusinov states (YSRs) with gate-tunable hybridization. Leveraging the field resilience of the superconducting lead, we resolve spin-split YSRs and we extract their g-tensor for multiple hybridization values.

*Speaker

Non-reciprocity in Josephson circuits

Tero Heikkilä * [1], Pauli Virtanen [1], Ilić Stefan [1], Dan Crawford [1], F. Sebastian Bergeret [2]

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I will describe two different ways of creating non-reciprocal responses in Josephson circuits. The recently actively studied Josephson diode effect is an effect where the junction exhibits a direction dependent critical current. The diode effect is a non-linear effect: its observation requires a large current. On the other hand, in multiterminal systems it is possible to create linear-response non-reciprocity leading also to non-reciprocal electromagnetic response of such circuits. Both effects can be realized via intrinsic and extrinsic approaches. In the previous case, the intrinsic properties of the junction, such as the combination of spin-orbit coupling and spin-splitting fields can do the trick, whereas an extrinsic way to get non-reciprocity can be obtained with phase bias in multiply connected structures. I will discuss the finite-frequency response in Josephson diodes and in the multiterminal systems and show how the latter can be used for creating on-chip circulators, very relevant for superconducting quantum electronics.

*Speaker

Theoretical aspects of superconductor-semiconductor hybrids and devices

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In the first hour of this tutorial, I will provide a pedagogical overview of the field of superconductor–semiconductor hybrids from the past 10+ years, including hybrid nanowires, planar heterostructures, Josephson junction arrays, Kitaev chains, non-Hermitian systems, etc. In the second hour of this tutorial, I will focus on one particular superconductor–semiconductor hybrid, known as full-shell nanowires. I will discuss fundamental aspects of these wires, such as the Little–Parks effect, Caroli–de Gennes–Matricon states, topology, and Majorana bound states, as well as several devices based on them. In the last 20 minutes, with the help of my PhD student, I will demonstrate how to define and numerically solve a prototypical project using the Julia-based package *Quantica.jl*. We will showcase how we, as theorists, go from an idea to the resolution and presentation of our results.

*Speaker

Superconducting transistors based on CVD graphene: toward superconducting integrated circuits

Andrey Generalov * [1], Markus Lehtisalo [1], Klaara Viisanen [1], Mikko Möttönen [2], Jian Ma [2], Kari Stadius [3], Shanuka Gamaethige [3], Jussi Ryynänen [3], Heorhii Bohuslavskyi [1]

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Realization of a superconducting field-effect transistor – the Josephson field-effect transistor (JoFET) – opens the way toward a new kind of voltage-controlled quantum electronics (1,2,3) and more efficient superconducting digital circuits (4). However, to advance beyond circuits composed of a few proximity junctions, a reliable wafer-scale technological platform needs to be developed.
In this work, we build upon our CVD graphene superconducting transistor platform (5). We study novel device geometries, further optimize the material stack, and demonstrate overall improvements in JoFET performance compared to the previous state-of-the-art in wafer-scale CVD graphene JoFETs (5). We fabricate the arrays JoFETs on 6" wafers with 98% yield and we observe a reproducible proximity effect in a dozen JoFETs covering short- to long-junction regimes with L varying from 150 to 700 nm. For our Al-graphene-Al junctions, we estimate the room temperature contact resistance Rc as low as 80 $\Omega\mu$m, mean free path of ~30 nm (diffusive regime), the superconducting proximity length of ~300 nm, and the induced superconducting gap of Δ^* ≈135 μeV as deduced from Multiple Andreev Reflections (MAR). For the shortest fabricated device ($L = 150$ nm, $W = 20$ μm), we obtain critical current density Ic normalized by W of 0.12 μA/μm, IcRn product of 60 μV (eIcRn/$\Delta^* \approx 0.44$), where Rn is the normal resistance, and nearly linear scaling of Ic with W for a given L. Finally, our junction transparencies reach values of
$tau = 0.4$.

With this JoFET platform development we proceed towards first demonstrators of JoFET devices and circuits consisting of multiple JoFETs and advance toward superconducting integrated circuits. In conclusion, we present a continuous advancement in the development of scalable superconducting transistors based on CVD graphene and discuss our roadmap toward realizing useful near-term circuit demonstrators supporting quantum processing units.

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Growth of hybrid nanowires with unconventional geometries for quantum devices

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Due to its ultrapure environment, molecular beam epitaxy (MBE) has been the preferred synthesis method of nanostructures, including III-V nanowires. Based on MBE growth, the recent progress on hybrid superconducting materials has been enabling research on quantum devices. For example, the improvement of the interface between semiconductors and superconductors have facilitated experiments searching for the emerging quantum states that have been predicted to be formed in semiconductor nanowires coupled to conventional superconductors (1). Motivated by these advances, designs and models have been proposed to explore those undiscovered quantum phenomena. Meanwhile, this comes with requirement of modifying the geometry of the materials and thus brings interesting challenges for nanowire growth.
Here, we report on several novel examples of hybrid nanowires with geometries different from that of the well-studied uniform wires. First, by inducing phase transition between wurtzite and zinc blende, quantum dots are formed within Josephson junctions. These nanowires can be used to develop superconducting qubits. Second, the diameter of full-shell nanowires is modulated along nanowires, forming bottleneck structures that are expected to reveal phenomena beyond the conventional Little-Parks effect for superconducting cylinders. Finally, we develop the geometry of InAs-Al-EuS nanowires avoiding contact between the ferromagnetic EuS shell and the InAs core. The geometry will simplify the corresponding theory and promote the study of superconducting states under intrinsic magnetic fields. We will discuss the feasibility and the difficulties to realize the geometries in terms of growth and results of structural characterization by TEM will also be shown. The exploration of growing these hybrid nanowires does not only provide the possibilities to fabricate intriguing devices for quantum transport but also help deepen the understanding of growth mechanisms.

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*Speaker

Poster presentations

Andreev reflection and quantized excess current in a Bilayer Graphene Quantum Point Contact

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We present a superconducting quantum point contact (QPC) realized in bilayer graphene using electrostatic confinement and coupled to a single aluminum superconducting electrode. In the normal state, the device exhibits conductance quantization in units of 4eˆ2/h. Upon entering the superconducting state, these plateaus are systematically enhanced due to Andreev reflection at the graphene–superconductor interface. Finite-bias measurements reveal a pronounced above-gap anomaly linked to the suppression of the Andreev excess current. Current-biased measurements show that this suppression occurs at a well-defined switching current that evolves in discrete steps as individual QPC modes are opened. These results demonstrate mode-resolved Andreev transport in a proximitized one-dimensional graphene channel and establish bilayer-graphene QPCs as a promising platform for hybrid superconducting devices.

*Speaker

Autonomous resetting a qubit by means of quantum heat engine

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We expand on the setup of autonomous resetting qubit by (Ali Aamir et al. Nature Physics vol. 21, 318–323 (2025)). Replacing one of transmons with a resonator (battery) we obtain a quantum heat engine. By setting up asymmetric couplings, we show that pumping the resonator up to a dozen photons is possible within experimentally achievable parameters. The resulting state is a doughnut shape, expressing stored useful energy. We add further two transmons, and implement autonomous reset by means of the battery. We show that for some regime of parameters, faster resetting is obtained than in the original scheme of the above paper. We present experimental proposal ready to be directly implemented.

*Speaker

Electron–Phonon and Thermal Transport Engineering in Phosphorene Nanoribbons for Quantum-Calorimetric Applications

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Recent progress in cryogenic detection technology has brought bolometers close to the quantum limit, enabling energy resolution and time-scales compatible with dispersive circuit-QED architectures and single-photon calorimetry. State-of-the-art quantum-ready bolometers-based primarily on epitaxial graphene, proximity-induced normal-metal nanowires, and Josephson-based absorbers-achieve noise-equivalent powers in the tens of zeptowatt range, sub-microsecond thermal response, and strong electron–phonon decoupling at millikelvin temperatures (1). These platforms rely on ultra-low electronic heat capacities and suppressed thermal conductance to maximise sensitivity to individual microwave or terahertz photons. Despite this progress, existing devices remain limited by material constraints such as residual disorder, restricted tunability of phonon spectra, or architectural incompatibility with scalable 2D integration (2).
The results of the study conducted during the project "Study of the effect of strain on the opto-electronic parameters of phosphorene nanostructures using quantum mechanics methods" (0063/DIA/2019/48) suggest that phosphorene nanoribbons represent a promising alternative material system for next-generation quantum-ready bolometers (3). Their inherently anisotropic phonon dispersion (4), strain-tunable thermal conductance, size-dependent band gaps, and strong directional electron–phonon coupling (5) offer a rich landscape for engineering hot-electron lifetimes and thermal isolation at cryogenic temperatures. Moreover, the quasi-one-dimensional geometry of nanoribbons enables extreme suppression of heat capacity, while the layered nature of black phosphorus permits integration with heterogeneous van der Waals platforms. This theoretical study explores the feasibility of phosphorene nanoribbons as the active element of quantum-ready bolometers using first-principles and multiscale simulations. We evaluate their electronic heat capacity and phonon-limited thermal conductance, accounting for strain-induced tunability of these properties. Projected performance is compared to the best existing graphene-based and metallic-nanowire bolometers. The results outline the fundamental limits, advantages, and design strategies for realising phosphorene-based quantum calorimeters capable of detecting microwave and terahertz photons at or near the single-quantum level.

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Critical temperature of ultra-thin aluminum films

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Recently, a thermally induced substitution process between aluminum and germanium has been demonstrated. This process allowed the formation of Al/Ge/Al hybrid junctions in nanowires (1). This same type of thermal substitution exists for aluminum and silicon and allows, in addition to Al/Si/Al heterojunctions, access to ultra-thin aluminum films with thicknesses around 1 nm. We measured the transport properties of these ultra-thin aluminum films. There are all superconductors and their critical temperature varies greatly with the thickness of the film.

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*Speaker

Finite-temperature scaling of voltage-tuned quantum phase transitions in a hybrid Josephson-junction array

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We report transport measurements of a two-dimensional semiconductor-superconductor hybrid Josephson-junction array with a double-layer electrostatic gate, enabling independent *in situ* voltage-tuned inter-island coupling and proximity-induced superconductivity. We use this voltage to drive and study superconductor-insulator (SIT) and superconductor-metal (SMT) transitions within the same device. For each transition, we identify the critical resistivity from isotherm crossings and extract critical exponents via finite-temperature scaling. We find that the critical resistivity approaches h/4eˆ2 near the triple point, where the superconducting, metallic and insulating states meet in the gate-voltage space. Away from this point, enhancing the proximity-induced coupling increases the SIT critical resistivity while the scaling exponent remains roughly constant. In contrast, increasing the inter-island coupling systematically decreases both the SMT critical resistivity and the associated exponent. This decrease roughly coincides with a voltage-tuned crossover of the metallic state from weak localization to weak antilocalization. Based on this we discuss whether the critical behavior is sensitive to the magnitude and sign of quantum-interference corrections in the metallic regime.

*Speaker

Parity-protected qubit based on Fourier engineering of the energy-phase relation

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One promising candidate for a protected superconducting qubit is the so-called cos2ϕ qubit, which employs nonlinear elements that enable coherent tunneling of Cooper pairs. This nonlinear element results in a Josephson potential containing only even harmonic terms, providing intrinsic protection against dielectric loss. In this work, we explore the realization of such a qubit using probably the simplest source of a non-sinusoidal current–phase relation (CPR): two Josephson tunnel junctions connected in series as described in Ref.(1). In this talk we demonstrate that this basic SIS–SIS configuration can exhibit an effective SNS-like CPR, supported by measurements of the qubit spectrum, and we discuss possible noise contributions within this system.

*Speaker

Scalable Al-Ge Hybrid Heterostructures for Next-Generation Superconducting Quantum Devices

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Hybrid superconductor-semiconductor systems offer a highly promising platform for quantum information processing. We present a top-down fabrication strategy for Al-Ge-Al quantum devices on GeOI substrates, enabling scalable integration of complex superconducting circuits with atomically abrupt, oxide-free interfaces. Ge structures are defined via optical and e-beam lithography, etched with RIE, and contacted using sputtered Al followed by thermal annealing. Building on prior results from bottom-up grown Al-Ge-Al nanowires demonstrating gate-tunable supercurrents and Multiple Andreev Reflections, the top-down platform now enables systematic exploration of temperature-dependent transport in defined Ge channels. This approach supports complex device geometries and large-scale integration for advanced quantum and cryogenic nanoelectronic applications.

*Speaker

Contact resistance and junction transparency of wafer-scale CVD graphene-based Josephson field effect transistors

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The Josephson Field Effect Transistor (JoFET) is a widely pursued and desired building block for future cryogenic electronic circuits. It offers the possibility to realize analog and digital cryogenic circuits operational down to millikelvin temperatures and, thanks to its dissipationless nature, JoFET circuits can consume only a fraction of the power required by, e.g., CMOS circuits. A scalable technology to produce JoFETs is essential for the development of novel and energy-efficient superconducting electronics. Recently, we reported progress in manufacturing reproducible JoFETs using gated Al-graphene-Al junctions on wafer scale. (1)

One of the main figures of merit for inducing the superconducting proximity coupling in superconductor–semiconductor junctions is the contact resistance RC. (2) In this work, based on our wafer-scale fabrication method of graphene JoFETs further improved from previous fabrication rounds (1), we reach width-normalized RC values as low as 60 $\Omega\mu$m, with a total wafer-scale device yield of ∼98%. A gaussian fit to the RC data, as has been done throughout the process to quantify process quality, gives a distribution of $<$ RC$>$ $= 167 \pm 70$ $\Omega\mu$m, an improvement over our previous results in Ref. (1). Based on the RC values, we perform device selection and observe superconductivity of the cooled-down devicesat cryogenic temperatures. Comparing junctions of different sizes, we observe linear scaling of IC with Wg, and cover short-to-long junction regimes. For the shortest fabricated device with Lg = 50 nm and Wg = 20 μm, based on the 4-probe measurements conducted at 30 mK, we extract a normal state resistance of RN ˜ 15 Ω and critical current of IC = 7 μA. Fitting the critical current versus temperature using the Kulik-Omelyanchuk model (3), we obtain a device transparency of ˜0.4 for this device, highlighting a high-quality junction.

In conclusion, we demonstrate that our JoFET wafer-scale technology allows us to create complex cryogenic classical and quantum superconducting electronics circuits with high maturity of the process and improved performance of the devices.

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*Speaker

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Probing intrinsic losses of a graphene Josephson junction

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Hybrid semiconductor–superconductor quantum circuits enable new functionalities and provide access to new physical regimes for devices, such as superconducting parametric amplifiers or qubits. Among the different realizations of qubits with gate-tunable Josephson junctions, graphene-based devices have so far shown limited coherence times, in particular compared to InAs nanowires. Losses, either at the superconductor/graphene interface or intrinsic to graphene itself, might be at the origin of these limitations.
In order to gain a deeper understanding of the intrinsic properties and losses of graphene-based Josephson junctions, we perform transmission measurements on a simple device consisting of such a junction embedded in a transmission line. From this, we obtain spectra dependent on gate voltage, current bias, and input microwave power. We expect these experiments to provide an enhanced comprehension of the dissipation mechanisms of graphene-based Josephson junctions, which will help improve existing and future hybrid qubit designs.

*Speaker

Shapiro spectrocopy of Josephson elements

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Hybrid platforms have emerged as excellent candidates for exploring emergent quantum phenomena arising from the intricate interplay between superconductivity and the tunability of semiconductors(1). In contrast to conventional SIS junctions, SNS junctions offer an additional degree of control through gate tunability of the normal region, making them ideal systems for studying the fundamental physics of proximity-induced superconductivity and enabling applications such as Andreev spin qubits(2), gate-tunable transmon(3), SQUIDs(4), Andreev crystals(5), and more. High-transparency SNS junctions exhibit current–phase relations (CPRs) with substantial higher-harmonic content. We use top contact on ultra-shallow Ge quantum wells to realize such gate-tunable JJs(3, 4).

In such hybrid SNS junctions-and more exotic analogs like STIS junctions(6, 7)-Shapiro spectroscopy serves as a powerful experimental technique for probing the CPR. The appearance or absence of certain integer or fractional Shapiro steps in the slow-driving regime (2eI_C R $>>$ hf) is often used to infer the harmonic content of these devices. However, this approach is frequently complicated by the sensitive dependence of experimental signatures on quasiparticle poisoning, heating, and other effects that make data interpretation challenging(6, 8, 9). Additionally, extracting the relative size of their harmonics remains a challenge, and usually an additional JJ in parallel is needed to perform DC SQUID spectroscopy.

In this work, we experimentally demonstrate a novel Shapiro spectroscopy technique, measuring the response of a Josephson element in the fast driving regime (2eI_C R $<<$ hf). The technique allows for the extraction of the full harmonic content of the CPR of a Josephson element. This is done using the shape of the critical current boundary of the zero-resistance domain in the presence of an RF drive (10). We experimentally verify this by performing the spectroscopy of a balanced SQUID, where the harmonic content is flux tunable. We exploit this tunability to perform the experiment with a predominantly $\sin(2\phi)$ CPR at half flux quantum, versus away from half flux quantum, where it is predominantly $\sin(\phi)$ CPR. With this, we show a stark difference in the Shapiro spectra of the driven SQUID in the two configurations, extracting the harmonic content for each case. This experiment establishes the proposed technique as a powerful complement to existing methods for probing the CPRs of Josephson elements(11, 12).
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Diffusive versus ballistic Little-Parks effect in superconducting rings and cylinders

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A thin superconducting ring or cylinder threaded by a magnetic flux exhibits a periodic modulation of its superconducting properties, known as the Little–Parks effect, typically with a flux quantum periodicity of Φ0. In this work, we study the emergence of an even–odd modulation in this effect, corresponding to an effective 2Φ0 periodicity, and examine how it compares between the diffusive and ballistic limits. In the diffusive regime, we compute the self-consistent complex order parameter using the nonuniform, arbitrary-temperature Usadel theory, formulated as the minimization of a grand-canonical functional over quasiclassical Gor'kov Green's functions. In the ballistic limit, we obtain a fully self-consistent Hartree–Fock–Bogoliubov solution through fixed-point iteration of the mean-field equations. The comparison between these two complementary frameworks reveals the role of nonlocal Green's function components and level quantization in producing the even–odd Little–Parks effect in ring and cylindrical geometries. (Work in progress.)

*Speaker

Optimizing one dimensional superconducting diodes: Interplay of Rashba spin-orbit coupling and magnetic fields

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The invention of diodes marked a pivotal moment in solid-state electronics, with their unidirectional current flow becoming a cornerstone of semiconductor technology. This concept of non-reciprocal current flow has now found its way into superconductivity, manifesting as the Superconducting Diode Effect (SDE). As non-dissipative circuit elements, superconducting diodes can unlock potentially revolutionary applications in quantum electronics, superconducting spintronics, and quantum information technology, ranging from high-quality rectifiers to advanced microwave sensors. SDE is characterized by the directional dependence of the depairing current- the critical threshold current at which a superconductor transitions to a normal metallic state. In this work, we investigate the SDE in helical superconductors that simultaneously break inversion and time-reversal symmetries, focusing on a prototypical Rashba nanowire proximitized by an s-wave superconductor and subjected to external magnetic fields. Using a self-consistent Bogoliubov–de Gennes mean-field formalism, we explore the intricate interplay between linear and higher-order spin–orbit coupling (SOC), supercurrent flow, and Zeeman fields. Our results demonstrate that Rashba nanowires with only linear SOC can achieve incredibly large diode efficiency 45% through the interplay of longitudinal and transverse magnetic fields. Notably, higher-order SOC enables finite diode efficiency even without a longitudinal Zeeman field, which can be utilized to reveal its presence and strength in nanowires. We present a comprehensive phase diagram of the device elucidating the emergent Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) superconducting state and demonstrate that proximitized Rashba nanowires offer a versatile, practical platform for SDE, with potential realizations in existing material systems. These results provide crucial insights for optimizing SDE in nanoscale superconducting devices, paving the way for next-generation dissipationless quantum electronics.

*Speaker

Superstrong Dynamics and Directional Emission of a Giant Atom in a Structured Photonic Environment

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Quantum emitters coupled to waveguides with nonlinear dispersion show rich quantum dynamics with the promise of implementing non-trivial non-Markovian quantum models. Recent advances in engineered photonic environments now allow the realization of discrete-site waveguides with tailored dispersion, yet most implementations of waveguide QED remain limited to a local qubit-waveguide coupling. Here, we study a transmon qubit non-locally coupled to a high-impedance coupled cavity array (CCA), thus implementing a giant atom in a structured photonic environment. The non-local coupling produces interference with the CCA modes, selectively enhancing interaction with even and long-wavelength modes, while suppressing coupling to odd and short-wavelength modes. For a subset of symmetric, long-wavelength modes, we reach the superstrong coupling regime. In this regime, measurements of the atomic participation ratio reveal strongly hybridized eigenmodes on a par with a strongly reduced qubit participation at the frequency of maximum hybridization with the qubit, in agreement with theory. Time-domain measurements of the qubit dynamics show clear deviations from the single-mode Jaynes-Cummings model, marked by the emergence of mode–mode interactions. By breaking spatial inversion symmetry of the CCA, the qubit seeds dressed eigenmodes confined to either the right or left of the qubit, which we exploit to implement and characterize a directional photon-emission protocol. These results demonstrate precise control over multimode light–matter interaction in a structured photonic environment

*Speaker

Towards Calorymetric Detection of Microwave Photons by Means of Proximity Effect

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Calorimetric single microwave photon detection remains one of the key challenges in modern experimental
physics, with direct implications for astronomy and emerging quantum technologies. The extremely small
photon energy in the microwave regime makes reliable detection particularly difficult. This study proposes
and analyzes a broadband calorimetric detector based on the superconducting proximity effect. In a normal
metal–superconductor (SN) hybrid structure, the proximity effect suppresses the metal's density of states
for energies below the superconducting gap. This suppression reduces the electronic heat capacity, thereby
enhancing the temperature rise following photon absorption beyond the electron–phonon noise limit. Our
goal is to develop a comprehensive theoretical description of the SN system using the Usadel and master
equations. Particular attention is devoted to the physical bounds on the achievable signal-to-noise ratio
and detection efficiency. Numerical simulations will subsequently be used to identify optimal material and
geometric parameters for device fabrication.

*Speaker

The ultra-short Josephson junction

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Planar Josephson junctions offer a platform for realizing topological superconductivity with minimal magnetic fields, a key advantage over nanowire-based proposals.
This is enabled by the flux tunability of the Andreev bound states and the short-junction regime, where the distance between the two superconductors is much smaller than the superconducting coherence length.
In this talk, I will introduce the iultra-short superconducting-normal-superconductor Josephson junction: a tunnel junction that proximitizes a two-dimensional electron gas.
I will show that this device hosts a minimal number of Andreev modes and is in the short-junction limit, a consequence of the distance between the two proximitized regions in the 2DEG.
I will demonstrate how ultra-short junctions optimize the design of Majorana zero modes, and enable anomalously large momentum transfer from the superconducting condensate to the quasi-particles they emit.

*Speaker

The influence of thermal current fluctuations on the apparent increase in critical current from the magnetic field.

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Recent literature attributes unusual magnetic-field dependences of the critical current, including apparent increases with field, to exotic superconductivity. We examine a more prosaic mechanism: fluctuation driven premature switching in Josephson junctions operated in the switching regime. Using the classical RCSJ model, we analyze switching distributions across three operating conditions: overdamped, underdumped, and quasi-regime, while varying temperature and other noise sources. We also consider the direct inclusion of the resistance or capacitance peak for a phenomenological attempt to description of the effect. Our results show that fluctuations allow the critical current to be changed by including the peak quite dramatically.

*Speaker

Development of gate-tunable nanowire Josephson junctions using novel strategies

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This work reports on novel strategies for building gate tunable nanowire Josephson junctions aimed at forming the building blocks of quantum circuits. We look for material combinations and designs that provide high superconducting current, hard superconducting gap, magnetic field resilience and tunability of the supercurrent flowing throught the weak link. We propose to use Sn as an alternative superconductor to Al in shadow defined hybrid InAs nanowire junctions. We demonstrate large critical currents up to 500 nA and magnetic field resilience up to 1 T. Alernatively, we propose the use of parallel nanowires as weak links of an Al/InAs based Josephson junction to increase the critical current flowing between the two contacts while maintaining gate tunability. Finally, we will discuss the scalability of such systems using III-V 2DEGs covered with Sn thin films.

*Speaker

Tuning Schottky barrier transparency in CoSi2/Si/CoSi2 junctions fabricated by using Ga focused ion beam

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Silicon (Si), due to its abundance, cost-effectiveness, and scalability, has revolutionized the modern electronics industry. It enables the fabrication of integrated circuits (ICs), transistors, and microchips, all essential components of a wide range of electronic devices. Furthermore, its ability to form a stable silicon dioxide (SiO) layer makes it ideal for developing metal-oxide-semiconductor field-effect transistors (MOSFETs), which are the fundamental building blocks of digital electronics. Superconducting silicides, such as cobalt disilicide (CoSi), are compounds composed of silicon and transition metals that exhibit superconductivity at low temperatures. These materials are highly promising for advancing quantum computing and superconducting electronics due to their unique combination of superconducting properties and compatibility with silicon-based technology. Silicide/Si platforms are particularly attractive candidates for realizing scalable superconducting Josephson field-effect transistors (JOFETs). However, a major challenge lies in the large Schottky barrier at the silicide/Si interface, which suppresses Cooper pair tunneling into silicon. Overcoming this barrier requires precise doping of the silicon to enable gate-tunable charge transport, preferably through a localized doping technique. In this work, we etched a 100 nm-wide trench into a CoSi transmission line using a gallium (Ga) focused ion beam (FIB), forming CoSi/Si/CoSi junctions. The use of high-energy (30 keV) Ga ions during trench milling not only defines the junction but also introduces Ga dopants into the exposed Si region. We demonstrate that varying the Ga ion dose enables control over the doping level in the Si region, thereby modulating the transparency of the Schottky barrier.

*Speaker

Unconventional magnetism and spin-orbit coupling in superconducting hybrid systems

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The field of superconducting spintronics has recently evolved from a focus on the interplay of superconductivity with ferromagnetism and various types of spin-orbit coupling, to include also unconventional types of magnetism such as altermagnetism and p-wave magnetism. Like spin-orbit coupling, these unconventional magnets can either be a bulk phenomenon or appear in a two dimensional material or interface, and they have a momentum-dependent spin-splitting that vanishes after averaging over the Fermi surface. However, unlike spin-orbit coupling, the underlying mechanisms break time-reversal symmetry. As discussed in this talk, this difference leads to qualitatively different transport responses in hybrid structures, both in equilibrium and out-of-equilibrium. To show this, first the transport equations for unconventional magnets with superconductivity are discussed, including the influence of the spin-dependent diffusion constant on Cooper pairs and an unconventional Larmor precession. Then, several effects are presented that are unique to hybrid systems with superconductivity and unconventional magnetism, and they are compared with effects that appear due to the interplay of superconductivity with spin-orbit coupling.

*Speaker

Switching dynamics of InAs/Al superconducting nanocircuits

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Integrated circuits with superconducting building blocks would have several benefits, such as high speed and low power consumption. In recent years, surprisingly, control of the supercurrent with voltage applied on a nearby electrode in all-metallic materials has been observed. This phenomenon can be used to fabricate gate-controlled transistors from superconducting materials, analogous to the field effect transistors. The suppression of the supercurrent was investigated in several materials, however there is no scientific consensus on the microscopical explanation (1-2).
We studied gate tuneable supercurrents in Al superconducting shells epitaxially grown on the top of InAs nanowires (3). We have investigated the properties of such switches using switching current distributions and shown the importance of fluctuations using noise measurements (4,5). We have also examined the switching dynamics of the investigated nanowire and analysed the possible switching speed of our device using both broadband pulsed measurements and by coupling them to superconducting resonators (6,7).

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*Speaker

Quantum Kinetic Uncertainty Relations in Mesoscopic Conductors at Strong Coupling

Gianmichele Blasi [1], Ricard Ravell * [2], Mykhailo Moskalets [3], Rosa López [2], Géraldine Haack [1]

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Kinetic Uncertainty Relations (KURs) establish quantum transport precision limits by linking signal-to-noise ratio (SNR) to the system's dynamical activity, valid in the weak-coupling regime where particle-like transport dominates. At strong coupling, quantum coherence challenges the validity of KURs and questions the meaning of the concept of activity itself. Here, we introduce a generalized dynamical activity valid at arbitrary coupling and derive a steady-state quantum KUR (QKUR) expressed in terms of this generalized activity. Explicit expressions are obtained within Green's function and Landauer-Büttiker formalisms. This QKUR ensures that uncertainty relations are valid across all coupling strengths, offering a general framework for out-of-equilibrium quantum transport precision analysis. We illustrate these concepts for paradigmatic quantum-coherent mesoscopic devices: a single quantum channel pinched by a quantum point contact and open single- and double-quantum dot systems.

*Speaker

Josephson anomalous vortices and rotary invariants

Dan Crawford * [1], Stefan Ilić [1], Pauli Virtanen [1], Tero Heikkilä [1]

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We show that current vortices, related to odd-frequency triplet superconductivity, appear in Josephson junctions where the barrier is a weak ferromagnet with strong spin-orbit coupling. These vortices are related to textures in the superconducting pairing amplitudes. By symmetry analysis we show that there is an additional term - a rotary invariant - in the superconducting free energy, even when the Lifshitz invariant vanishes. We show via microscopic simulations that the size, shape, and position if these vortices can be controlled by manipulating spin-orbit coupling in the weak link, via gates. We suggest that these vortices could be detected by scanning magnetometry techniques.

*Speaker

Transmon qubit using Sn as a junction superconductor

Sergey Frolov * [1]

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Superconductor qubits typically use aluminum-aluminum oxide tunnel junctions to provide the non-linear inductance. Junctions with semiconductor barriers make it possible to vary the superconductor material and explore beyond aluminum. We use InAs semiconductor nanowires coated with thin superconducting shells of beta-Sn to realize transmon qubits. By tuning the Josephson energy with a gate voltage, we adjust the qubit frequency over a range of 3 GHz. The longest energy relaxation time, T1 = 27 microseconds, is obtained at the lowest qubit frequencies, while the longest echo dephasing time, T2 = 1.8 microseconds, is achieved at higher frequencies. We assess the possible factors limiting coherence times in these devices and discuss steps to enhance performance through improvements in materials fabrication and circuit design.

*Speaker

February 4, 2026

Oral presentations

Superconductor/Semiconductor Heterostructures for Quantum Computing Applications

Christopher Palmstrom * [1]

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TBA

*Speaker

Effect of Joule heating & Inverse Proximity Effect on device characteristics

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[2] Universidad Autonoma de Madrid – Spain

In contacting a mesoscopic device by current probes, one expects that the measured I-V's yield information on the 'bare' properties of the device. In this talk, I will present theory and data that shows the unexpected impact from Joule heating and inverse proximity effect on I-V characteristics of nanowires. This results in a significant *observer effect,* meaning that the act of measurement itself influences the system under scrutiny. Here, I focus on measurements on full-shell InAs/Al nanowire connected to metallic leads in a four terminal setup, which significantly alters the superconducting shells properties. This observer effect leads to a sharp drop in switching current and the emergence of an anomalous metallic phase with low but finite resistance. We find that this regime of anomalous resistance is stabalized by a balance of inverse proximity and joule heating. We explain these results by accounting for the inverse proximity effect within the Usadel theory of diffuse superconductors in 1D simulations of the device geometry. Using the Little-Park effect as a knob to tune superconductivity, we test this hypothesis and find excellent agreement between data and theory. This observer effect might explain other instances of anomalously small switching currents measured in hybrid superconductor-semiconductor devices, and serve as a source of disorder in low dimensional superconductors hindering technological applications.

*Speaker

Mapping dissipation in a quantum dot junction

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Characterization of quantum devices relies primarily on electrical properties. It is usually assumed that all parts of the device remain at the same temperature. However, the inevitable presence of local dissipation can lead to significant deviations (1). Measurements of dissipation or heat transport are more involved and therefore less prominent in the literature (2).
Here, we present a device capable of measuring simultaneously the dissipation generated by the current through the quantum dot junction, as well as the current itself. To this end, we thermally isolate the drain contact of an epitaxially defined quantum dot in an InAs nanowire. The electron temperature of the drain is measured via the zero-bias conductance of a proximitized tunnel junction (3). Furthermore, we employ radio-frequency techniques, enabling us to measure the electron temperature on μs-timescales, corresponding to the typical thermalization set by electron-phonon interactions.

As a first demonstration of the device's capabilities, we map the dissipation across the whole operational range of gate- and bias-voltages. We identify regimes where, due to Coulomb blockade, power dissipated in the drain can be tuned solely by the gate voltage, while both the current through and voltage across the quantum dot are kept constant.

The presented device therefore enables future investigations of local dissipation in nanoscale devices, in particular with the objective to mitigate detrimental heating effects, as well as implementations of proposed experiments in the field of quantum thermodynamics.

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(3) Karimi, B & Pekola, J.P., *Phys. Rev. Applied* **10**, (2018) 054048

*Speaker

Monolithic Metal-Semiconductor Heterojunctions Enabling Adaptive Computation at Cryogenic Temperatures

Masiar Sistani * [1], Andreas Fuchsberger , Nikolas Knaller [1], Lukas Wind [1], Viktor Wahler [1], Daniele Nazzari [1], Lilian Vogl [2], Peter Schweizer [2], Enrique Prado Navarrete [3], Johannes Aberl [3], Moritz Brehm [3], Walter M. Weber [1]

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[3] Institute of Semiconductor and Solid State Physics, JKU Linz – Austria

Conventional ultra-scaled metal–oxide–semiconductor field-effect transistors (MOSFETs) form the backbone of complementary metal–oxide–semiconductor (CMOS) technology and dominate analog and digital electronics. However, for cryogenic applications ranging from quantum system readout circuits to large-scale low-temperature data processing, conventional CMOS technology reveals its limitations. At ultra-low temperatures, phenomena such as dopant freeze-out, band tailing, and threshold voltage upshifts severely compromise the device performance metrics. To overcome these challenges, cryogenic CMOS (cCMOS) devices are foreseen to enable new levels of high-performance computing featuring enhanced subthreshold slopes, lower threshold voltages and high drive current at comparably low supply voltages. Unlike devices that rely on doping, SBFETs retain conductivity at cryogenic temperatures, and their streamlined device architecture simplifies fabrication. Especially for adaptive electronics, SBFET-based reconfigurable field-effect transistors (RFETs) are particularly compelling. By combining NMOS and PMOS functionality within a single universal device, they enable compact circuit designs that expand functional density, and reduce power consumption. This enables logic circuits that can be run-time reprogrammed, adapting and optimizing their function with respect to the desired application. Despite these promising features and the motivation of having run-time reconfigurable analog and digital components for quantum computation, RFETs operating at cryogenic temperatures remain largely unexplored. This talk discusses SOI-based SBFETs and RFETs with monolithic Al contacts operable at cryogenic temperatures as low as 4.5 K. In this regard, Si- and Ge-based RFETs demonstrate high and symmetric on-states for both NMOS and PMOS mode, with drain current modulation spanning nine orders of magnitude and subthreshold slopes of about 20 mV/dec. To further improve the cryogenic performance of Si-based p-type SBFETs, ultra-thin SiGeSn layers are integrated atop the SOI. Combined with monolithic quasi-ohmic Al contacts and a multi-gate transistor design that suppresses reverse junction leakage, this approach yields a fivefold enhancement in on-current and a threefold increase in peak transconductance compared to SOI reference devices. At cryogenic temperatures, measurements show drain current modulation over nine decades with subthreshold slopes of 20 mV/dec below 50 K, alongside a 50% reduction in threshold voltage. Importantly, the on-currents remain largely

*Speaker

temperature-independent, highlighting the potential of these devices for cryogenic computing. Additionally, the transition of the single-elementary Al contacts into a superconducting state (at 1.25 K) and the high contact transparency of the proposed devices may give rise to novel physical phenomena, potentially reshaping design strategies and paving the way for quantum computing applications.

Andreev Physics in Hybrid Josephson Junctions

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The Josephson effect, which describes the coupling between two superconductors through a weak link, is the basis of several quantum devices. While it has mainly been harnessed in tunnel junctions, hybrid Josephson junctions – in which quantum conductors serve as weak links – offer a rich landscape of physics to explore. In such systems, the Josephson effect arises from the presence of Andreev bound states: fermionic states localized at the weak link, whose properties depend on the superconducting phase difference across the junction. In this two-hour tutorial, I will present this research field, introducing key theoretical concepts and highlighting experimental realizations.

*Speaker

Electrically tunable Josephson parametric amplifier based on graphene Josephson junctions

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Parametric amplifiers are crucial components in the field of superconducting quantum circuits. They are essential to readout of qubits with the best fidelity thanks to their quantum limited noise and can produce non classical states of light. There have been developments in recent years to use a semiconductor weak link as an electrically tunable source of nonlinearity, serving as the building block for these amplifiers (1,2,3,4). Here, we use a graphene Josephson junction as the semiconductor weak link 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. We also discuss the squeezing properties of the amplifier.

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*Speaker

Hybrid InAsSb double quantum dots in nanowires with epitaxial Al leads and crystal phase defined barriers

Pawel Sidorczak * [1], Rasmus D. Schlosser [1], Yu Liu [1], Martin Bjergfelt [1], Jakob Maria Heidweiler [1], Thomas Kanne [1], Joachim Sestoft [1], Jesper Nygård [1]

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Crystal phase defined quantum dots in semiconductor nanowires (1) are an elegant alternative for use of quantum dots in 2DEG devices, due to possible integration with conventional metallic superconductors via epitaxial matching, in addition to improving the consistency of fabrication, reducing the number of required control gates and improving reproducibility of devices. In this presentation we will demonstrate the realization of double quantum dots (DQD) in InAsSb/InAs nanowires with epitaxial aluminium half-shell, recently grown for the first time. Segments of nanowires are characterized with Transmission Electron Microscopy.

Devices are fabricated by etching the aluminium shell over the DQD and using the remaining aluminium as superconducting source/drain leads. In addition devices with shadow defined S-DQD-S junctions will be presented (2).

Transport measurements are analysed in terms of Andreev bound states, Yu-Shiba-Rusinov states and multiple Andreev reflection (3). These devices have high potential for quantum simulations due to the possibility of efficient coupling to superconducting resonators and validate the use of this material for more complicated hybrid devices.

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*Speaker

The InAs-on-Insulator Platform for Hybrid Superconducting Electronics

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The InAs-on-Insulator (InAsOI) platform constitutes an emerging architecture for hybrid superconducting electronics, offering a versatile route toward planar, high-performance quantum devices that are fully compatible with large-scale cryogenic integration (1). The structure consists of a thin semiconducting InAs epilayer, doped on-demand with Si atoms, epitaxially grown on a metamorphic InAlAs buffer. This buffer acts as an efficient cryogenic electrical insulator, providing electrical isolation between neighboring components while preserving excellent electronic transport in the active Si-doped InAs layer. The concept mirrors the highly successful Silicon on Insulator (SOI) technology in conventional semiconductor electronics, extending its design principles into the superconducting regime. As such, InAsOI combines large supercurrent densities tunable with the Si-doping level, precise electrostatic control via the gate voltage, and superior scalability, establishing a foundation for the next generation of hybrid quantum and cryogenic devices.
Within this platform, hybrid Al–InAs–Al Josephson junctions (JJs) have been fabricated and thoroughly characterized, displaying critical current densities as high as 7.3 μA/μm. Their behavior under out-of-plane magnetic fields follows a Fraunhofer-like interference pattern, a hallmark of coherent Josephson coupling across the semiconductor channel. These results confirm a robust superconducting proximity effect throughout the InAs layer and demonstrate that InAsOI can host highly transparent superconducting weak links. Building on this capability, the integration of gate insulators enabled the realization of gate-tunable Josephson Field Effect Transistors (JoFETs) (2). By applying gate voltages of only a few volts, the critical current can be continuously tuned or entirely suppressed, accompanied by >10 increase in the normal-state resistance.

Leveraging these JoFETs as active superconducting switches, we demonstrate for the first time the time-division multiplexing (TDM) of nondissipative supercurrents (3). InAsOI-based superconducting demultiplexers achieve operation bandwidths $>$ 4GHz in signal frequency and 10 MHz in switching frequency at 50 mK, while maintaining near-zero insertion loss and an ON/OFF ratio of approximately 17.5 dB.

Beyond TDM, the InAsOI platform has also enabled the experimental demonstration of nonreciprocal supercurrent transport, ferroelectric programmability of the Josephson effect, and caloritronic control of heat flow. These achievements highlight InAsOI as a uniquely versatile and multifunctional platform for superconducting quantum electronics, unifying signal routing,

*Speaker

non-linear control, and thermal management within a single, scalable hybrid technology.

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Multiterminal Andreev spin devices

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Andreev spin qubits combine the strong coupling to superconducting resonators, characteristic of superconducting qubits, with the compact geometries of spin qubits. Unlike conventional spin qubits, they do not require an external Zeeman field to achieve spin splitting. However, in standard two-terminal setups, this splitting is limited by the spin–orbit length. We show that multiterminal configurations offer an effective route to enhance and control spin splitting in these devices. We develop a model Andreev spins coupled to an arbitrary number of leads and analyze the spin texture of the spectrum as a function of the superconducting phase differences. Our results demonstrate that multiterminal geometries enable tunable spin–phase coupling, providing new opportunities for designing hybrid superconducting quantum devices.

*Speaker

Self-correcting GKP qubit and gates in a driven-dissipative circuit

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Gottesman, Kitaev, and Preskill proposed to encode a qubit in a remarkable wavefunction, which satisfy location and momentum constraints simultaneously. Such a state offers superior error correction, but is rather hard to achieve and stabilize. We propose a circuit architecture for a dissipatively error-corrected GKP qubit. The device consists of a high-impedance LC circuit coupled to a Josephson junction and a resistor via a controllable switch. When the switch is activated via a particular family of stepwise protocols, the resistor absorbs all noise-induced entropy, resulting in dissipative error correction of both phase and amplitude errors. Furthermore, the proposed architecture provides new implementation for gates and readout. In my talk I'll introduce the GKP construction and explore our proposal for its realization.

*Speaker

Quasi-Ballistic InGaAs Josephson Field-Effect Transistor with Molybdenum Electrodes

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We have fabricated, measured and modeled Mo-InGaAs-Mo Josephson field-effect transistors (JoFETs) (1). The contacts were fabricated using sputtered molybdenum on top of highly doped InGaAs, with an HCl cleaning before deposition, achieving a rather low contact resistance of 30 $\Omega\mu$m. This is, to our knowledge, the first-time molybdenum has been used to fabricate Josephson junctions and opens new opportunities for realizing transparent superconductor–semiconductor interfaces. We believe that molybdenum is an interesting material choice since it has similar superconducting properties to aluminum with long bulk coherence length and can be integrated with the InGaAs platform using a simple *ex situ* fabrication technique. The use of an n InGaAs cap together with Mo is a proven III-V MOSFET technique for forming ohmic contacts with low contact resistance. Lattice-matched InGaAs two-dimensional electron gas (2DEG) systems grown on InP combine high electron mobility and low effective mass with the planar, uniform, and gate-tunable nature of the 2DEG, enabling fast, low-noise carrier transport and reproducible, scalable architectures for future superconductor–semiconductor hybrid devices.
The JoFETs were characterized using current driven four-terminal measurements at cryogenic temperatures in a dilution refrigerator with a base chamber temperature of 15 mK. Multiple Andreev reflections (MAR) are observed up to fourth order, and the measured temperature dependence of the MAR peaks is consistent with a model describing an effective induced superconducting gap beneath the contacts. We observe a proximity-induced superconducting gap of $\Delta^* \approx 110\ \mu$V ≈ 55 % of the size of the gap in the molybdenum film and a high value of the product of the excess current and the normal resistance IR/$\Delta \approx 1.5$, which corresponds to Z $\approx$ 0.44, indicating a good interface quality between the Mo and n InGaAs. We also show that the gate dependence of the critical current can be accurately reproduced using a straightforward quasi-ballistic model that considers contributions from both Andreev states in the discrete spectrum and leaky states in the continuous spectrum. The model, which only uses the mobility from the normal state resistance and the induced gap from multiple Andreev reflection as input parameters, can be a suitable model for large-scale integration of hybrid devices.
(1) L. Olausson and E. Lind, (manuscript submitted), (2025)

*Speaker

Graphene-based Josephson devices for highly sensitive bolometry

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Bolometers are radiation sensors that are central to wide areas such as dark matter search, radio astronomy, material science, and qubit readout, among others. There have been different realizations of bolometers using superconducting thin films, nanowires, and various 2D materials in the recent past. The challenge is to have a single device that combines high sensitivity, a fast readout mechanism, and low noise. In this work, we demonstrate a new readout scheme for bolometers using a graphene-based Josephson parametric amplifier (JPA)1,2. Our key finding is that the Kerr non-linearity of the JPA boosts the device's sensitivity. When the bolometer is biased in the non-linear regime, it enhances the sideband signals (_˜100 times), resulting in an order of magnitude improvement in sensitivity compared to the linear regime. Our work integrates a JPA into a bolometer, enabling a fast and sensitive operation compared to previously studied graphene-based bolometers. Our study demonstrates a way forward to improve the quantum sensors based on 2D materials by leveraging the inherent non-linear response.

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*Speaker

Probing the parity of Quantum dot-hybrid systems with gate reflectometry

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Quantum dot coupled to superconductors has been proved to be a reliable platform to realize Kitaev chain and a promising way to realize parity qubits with Majorana modes. Quasiparticle poisoning in quantum dot-superconductor systems is a fundamental challenge for the life time in such hybrid systems. Gate reflectometry allows fast, noninvasive detection of quantum capacitance associated with quasiparticle poisoning events flipping the parity. Here we study two quantum dots coupled by a semiconductor-superconductor hybrid region in a two-dimensional electron gas, using reflectometry to probe the parity of the system. We observe quasiparticle poisoning events flipping the parity from both quantum dot plunger gates and from the superconductor. The technique is useful for further study on similar systems such as Kitaev chain and qubits made with Kitaev chain.

*Speaker

February 5, 2026

Oral presentations

Theoretical aspects of superconductor-semiconductor hybrids and devices

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In the first hour of this tutorial, I will provide a pedagogical overview of the field of superconductor–semiconductor hybrids from the past 10+ years, including hybrid nanowires, planar heterostructures, Josephson junction arrays, Kitaev chains, non-Hermitian systems, etc. In the second hour of this tutorial, I will focus on one particular superconductor–semiconductor hybrid, known as full-shell nanowires. I will discuss fundamental aspects of these wires, such as the Little–Parks effect, Caroli–de Gennes–Matricon states, topology, and Majorana bound states, as well as several devices based on them. In the last 20 minutes, with the help of my PhD student, I will demonstrate how to define and numerically solve a prototypical project using the Julia-based package *Quantica.jl*. We will showcase how we, as theorists, go from an idea to the resolution and presentation of our results.

*Speaker

A gate tunable transmon in the ultrastrong coupling regime

Ignacio Casal Iglesias * [1,2], Gorm Ole Steffensen [3,4], Francisco Jesus Matute-Cañadas [2,5], Ángel Ibabe [1,2], Lukas Splitthoff [6], Marina Calero De Ory [7,8,9], David Rodriguez [7,8,9], Daniel Granados [10], Alicia Gomez [7,8,9], T. Kanne [11], Jesper Nygård [11], Ramon Aguado [3,4], Alfredo Levy Yeyati [2,4,5], Eduardo Lee [1,2,4]

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[2] Condensed Matter Physics Center (IFIMAC) and Instituto Nicolás Cabrera (INC), Universidad Autónoma de Madrid, 28049 Madrid, Spain – Spain
[3] Instituto de Ciencia de Materiales de Madrid – Spain
[4] Laboratorio de Transporte Cuántico, Unidad Asociada UAM/ICMM-CSIC, Madrid, Spain – Spain
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The ultrastrong coupling regime of light–matter interaction, where the coupling rate becomes a sizable fraction of the resonator frequency, opens access to quantum electrodynamics beyond the rotating-wave approximation. While this regime has been studied in different superconducting circuits, its realization in hybrid semiconductor–superconductor systems remains largely unexplored. This work presents the experimental investigation of a gatemon qubit based on a hybrid InAs-Al nanowire in the ultrastrong coupling limit. From the measurements, we estimate a vacuum Rabi splitting of g_0/h = 648 MHz, corresponding to a ratio $g_0/f_r >$ 0.16. Further evidence of the ultrastrong coupling is obtained by means of spectroscopic measurements that probe the qubit transition for different photon occupancies of the resonator, which reveal a unique spectral signature of this regime.

*Speaker

Fluxoid solitons in superconducting tapered tubes and bottlenecks

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A thin-walled tubular superconductor develops a quantized fluxoid in the presence of an axial magnetic field. The fluxoid corresponds to the number of phase windings of the superconducting order parameter and is topological in nature. When the tube has a radius variation along the axial direction, forming a bottleneck structure between sections with different radius, a fluxoid mismatch can appear at the bottleneck depending on the applied magnetic field. This constitutes a topological boundary and is host to topologically protected solutions for the order parameter, dubbed fluxoid solitons, which are free to move around the bottleneck. Fluxoid solitons also constitute a new type of vortex with non-quantized flux, loosely related to Pearl vortices in thin superconducting films and Josephson vortices in Corbino Josephson junctions. We characterize their properties as a function of system parameters using the self-consistent quasiclassical theory of diffusive superconductors. We consider both short bottleneck structures and long tapered tubes, where multiple fluxoid solitons can be trapped, and adopt elaborate arrangements dictated by their mutual repulsion.

*Speaker

Uncovering Emergent Quantum Phenomena in High-Mobility InAs Quantum Well Structures

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Indium arsenide (InAs) has a large magnitude Landé *g*-factor of ˜ 15, making it an excellent material for investigating strong spin–orbit coupling in low-dimensional devices. In addition, InAs quantum wells (QWs) exhibit exceptionally high mobilities ($> 1\times10$ cm^2/Vs), and near-surface QWs have demonstrated gate-tunable, proximity-induced, superconductivity, establishing them as an ideal platform for studying topologically non-trivial, hybrid heterostructures. Recent advances in epitaxial growth and device engineering have positioned InAs QWs grown on InP substrates as the leading material system for this quantum technology. The record mobilities are achieved through the use of strain-compensated heterostructures with increasing QW thickness (1). I will present experimental results on one-dimensional electron transport and spin–orbit interaction effects in these structures. Using gate-defined quantum point contacts, we observe ballistic one-dimensional conductance quantization with up to 17 plateaus and report non-magnetic fractional conductance states at $0.2\times(e^2/h)$ and $0.1\times(e^2/h)$, arising from strong electron–electron interactions and momentum-conserving backscattering within quasi-one-dimensional channels, potentially indicative of correlated or entangled charge states (2). Here e is the unit of charge and h in Planck's constant. Transverse electron focusing experiments reveal a characteristic three-peak structure resulting from the interplay between Rashba and Dresselhaus spin–orbit coupling, offering a direct insight into spin-dependent cyclotron dynamics. Complementary studies on Nb–InGaAs Josephson junctions demonstrate the formation of a hard superconducting gap and highly transparent interfaces (with transmission coefficient > 0.96), confirming the suitability of InAs-based heterostructures for ballistic Andreev transport and future topological superconducting device applications (3). These results demonstrate that high-quality InAs-based heterostructures are a powerful platform for combining spin–orbit physics, many-body quantum effects and hybrid superconducting quantum device operation.

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Low-temperature growth of superconductors at wafer scale

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The epitaxial growth of superconducting thin films under controlled conditions is crucial for advancing quantum technologies. Here, we report on the low-temperature molecular beam epitaxy (MBE) growth of superconducting materials performed at cryogenic temperatures. Operating at reduced temperatures effectively suppresses surface diffusion and intermixing, enabling precise stoichiometric control and the suppression of unwanted secondary phases. Remarkably, even under these constrained thermal conditions, the films exhibit single-crystalline epitaxial growth, as evidenced by high-resolution X-ray diffraction and transmission electron microscopy analyses. The resulting structural perfection should lead to enhanced quantum coherence and a significant improvement in the superconducting critical temperature (Tc) compared to polycrystalline or amorphous counterparts. These results demonstrate that cryogenic MBE provides a viable pathway for the synthesis of highly ordered superconducting heterostructures at wafer scale, paving the way for their integration into next-generation quantum and superconducting electronic devices.

*Speaker

Wafer-scale CMOS-compatible fabrication of hybrid Josephson devices

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Hybrid components and devices based on proximitized semiconductor channels enable pathways towards critical advances in performance, miniaturization and scalability of superconducting electronic architectures.
The functional traits of field gating, non-linear and non-reciprocal signal response in Josephson field-effect transistors (JoFETs) and superconducting diodes (SDs) are enabling the transition from bulky dissipative cryodevices like isolators, circulators, multiplexers, and amplifiers to their on-chip equivalents.

The technological impact provided by hybrid Josephson devices depends both on the scalability of the required cryogenic systems and on the successful adoption of the device fabrication protocols on an industrial scale. These challenges motivate the development of CMOS-compatible, wafer-scale fabrication processes that enable the use of superconducting materials with He3-free cryogenics.
Here we show recent advances in design, fabrication and operation of hybrid Josephson components that utilize silicon channels in combination with superconductors possessing a higher critical temperature than aluminum. Notably, we employ device processing steps developed with consideration for interoperability with established very-large scale integration (VLSI) foundry protocols.

*Speaker

Microwave characterization of InAs based Josephson devices

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Semiconductor-superconductor hybrid nanocircuits are of high interest due to their potential applications in quantum computing. Semiconductors with a strong spin-orbit coupling and large g-factor are particularly attractive since they are the basic building blocks of novel qubit architectures. We have investigated the current phase relation of an InAs 2DEG based RF-SQUID using the in-situ epitaxially grown Al layer as superconducting material to demonstrate the microwave compatibility. Using nanowires instead of 2DEGs allows us to reach the few channel limit, where two-tone spectroscopy reveals the Andreev spectra of the Josephson junction. In such a device we have demonstrated a close to ultrastrong ABS-photon coupling in the quantum dot regime. Placing two Josephon junction closer than the coherence length allows for the formation of Andreev molecular states, which are investigated in both platforms.

*Speaker

Poster presentations

A Proximitized Quantum Dot in Germanium: A Building Block for Highly Coherent Andreev Spin Qubits

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1

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The Andreev spin qubit (ASQ) combines the advantages of semiconductor spin qubits and superconducting qubits(1)(2). It inherits the compact footprint and gate tunability of semiconductor spin qubits, while offering long-range coupling capabilities typical of superconducting qubits. Coupling between spatially separated ASQs via superconducting loops has been demonstrated in III-V semiconductor platforms(3). However, conventional readout methods based on circuit quantum electrodynamics require large resonators that hinder scalability and are difficult to implement on heterostructures without complex techniques such as flip-chip bonding. Moreover, ASQs fabricated on III-V materials suffer from magnetic field noise due to nuclear spins(4). On the other hand, spin-to-charge conversion techniques such as Pauli spin blockade-widely used in semiconductor spin qubit architectures-offer a promising route to compact ASQ readout. Germanium heterostructures present a compelling alternative to III-V materials, offering strong spin-orbit coupling, transparent superconductor-semiconductor interfaces, and the possibility of isotopic purification to eliminate nuclear spin noise(5).

Here, we present the first quantum dot in planar germanium proximitized by a superconducting lead(6). By tuning the coupling between the quantum dot and the superconducting lead, and consequently the ratio between charging energy and superconducting pair potential, we demonstrate controlled ground state transitions between singlet and doublet configurations. These transitions mark a critical prerequisite for operating Andreev spin qubits, as they enable controlled access to spin-dependent ground states. Building on this result, we aim to integrate proximitized quantum dots into superconducting loops for phase biasing, and employ adjacent quantum dots for Pauli spin blockade readout. Finally, we outline a potential layout for a scalable architecture of spin qubits in germanium that integrates both ASQs and conventional spin qubits, paving the way toward scalable quantum processors in germanium.

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*Speaker

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Full Counting Statistics in a DQD–Resonator system driven by Squeezed Light

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We study a hybrid microwave quantum device consisting of a double quantum dot (DQD) embedded in a superconducting resonator, motivated by recent experiments demonstrating zero-bias microwave-to-electron conversion. Using a theoretical description based on a Jaynes–Cummings–type Hamiltonian and a Lindblad master equation, we analyse electron transport in the presence of a non-classical squeezed microwave drive. Full counting statistics (FCS) is introduced to characterise current fluctuations and the Fano factor beyond average transport quantities. As a reference, we outline the well-established FCS of a single quantum dot and discuss how squeezing modifies the drive term in the Hamiltonian. The goal of this work is to establish a framework for predicting how squeezed input fields imprint themselves on transport noise, forming the theoretical basis for future experimental studies.

*Speaker

Hybrid quantum dot devices in magic-angle twisted bilayer graphene

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Magic-angle twisted bilayer graphene (MATBG) has emerged as a tunable material, hosting superconducting, semiconducting and insulating phases (1,2). Combining the phases that MATBG offers, quantum devices like Josephson junctions (3,4), rings (5), and point contacts (6) have been realized.

We explore MATBG as a novel platform hosting semiconductor-superconductor quantum dot devices, where different phase combinations can be engineered within a single device. We demonstrate carrier confinement through Coulomb blockade and explore transport in two distinct regimes: a superconducting island and a quantum dot Josephson junction (S-QD-S).

In the superconducting island regime, we observe the parity effect with a complete 2e to e crossover of the carrier charge as a function of magnetic field. In the S-QD-S regime, we observe an even-odd modulation of the Andreev bound state spectrum, compatible with the formation of Yu-Shiba-Rusinov states.

Our work introduces MATBG as a new material platform for realizations of quantum dot hybrid devices combining collective electronic phases.

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*Speaker

Anomalous phase shift in ferromagnetic hybrid Josephson junctions

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We report low-temperature transport measurements in hybrid Josephson junctions comprising semiconducting InAs nanowires with partially overlapping epitaxial ferromagnetic-insulator (FI) EuS and superconducting (S) Al shells. Using a voltage-tunable SQUID geometry, we measure the current–phase relation and observe a distinct ϕ-phase shift accompanied by a magnetic-field-induced 0–π phase transition. The anomalous phase behaviour likely originates from the interplay between broken time-reversal symmetry due to the ferromagnetic EuS layer and broken inversion symmetry arising from Rashba spin–orbit coupling in the InAs nanowire. This combination generates spin-polarized supercurrents with intrinsic phase offsets in the S/FI/S junctions. In addition, we investigate how the ϕ shift evolves as we electrostatically tune the charge carriers through different gates in the SQUID. The results demonstrate a controlled interplay between superconductivity and ferromagnetism in spin-orbit coupled nanowires, a platform suited for nonreciprocal supercurrent transport and protected quantum state generation.

*Speaker

Inductively Protected Andreev Spin Qubit (IPA-SQ)

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Qubits use quantum superpositions to encode and process quantum information. However, unlike conventional bits, this makes them extremely susceptible to environmental fluctuations, leading to decoherence and relaxation. This has motivated the search for protected qubits that minimize sensitivity to these perturbations, extend coherence times, and improve the scalability of quantum processors.

Here, we present a new protected-Andreev-spin qubit design based on a superconductor–semiconductor hybrid platform (1). We use a fluxonium qubit with a well-defined quantum dot Josephson junction, which leads to a spin-split doublet ground state. The addition of an inductor (EL) provides the potential landscape to tune the system into a sweet spot, gaining phase-noise protection and enabling the separation of spin states of the quantum dot into two different minima (fluxonium sweet spot), controlled by the ratio between the Josephson and inductive energies (EJ/EL).

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*Speaker

Superconducting Silicon Josephson Junctions: Reliable fabrication and supercurrent manipulation

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Silicon is one of the most widely-used material in electronic devices. However, it's less well-known that it is superconducting when hyperdoped with boron. Although the critical temperature is below 1 K, the compatibility with CMOS-technology makes hyperdoped silicon an interesting material to implement devices that combine not only semiconducting, metallic and superconducting Si, but also Si integrated photonic devices. To reach the active concentration necessary for superconductivity ($>$ 1 at. %), well above the equilibrium solid solubility limit, nanosecond laser doping is required, as the very fast epitaxial recrystallisation make it possible to achieve hyperdoping. One of the disadvantages of laser doping, however, is that it is difficult to spatially vary the doping below the diffraction limit associated to the nanosecond laser wavelength, λ=308 nm in our case, and thus create sub-μm devices.
For instance, the first all-silicon Josephson junctions, with lengths of the order of 100 nm, were fabricated from a superconductor (S)/doped semiconductor (sc) bilayer. The 60 nm thick S top layer was locally etched, leaving the 20 nm sc below to act as the junction's weak link. To prevent damaging the weak link underneath, the etching depth accuracy has to be below 5 nm, thus requiring precise calibration and making this step difficult to perform reliably. To get around this bottleneck, we have implemented a new method of fabricating planar SscS-junctions using masked ion implantation. The control over the doping spatial modulation is now only limited by the lateral boron diffusion during implantation and the following fast laser anneal employed to fully activate the dopants. The first results show that this method yields Josephson Junctions with a full proximity effect.
Using this promising method we are now working towards the manipulation of the supercurrent. On one hand, we have started investigating the effect of an electrostatic gate on the supercurrent. On the other, we conducted the first tests on the hyperdoping of photonics-compatible SOI. With these components we aim to create devices that can be used as building blocks to combine integrated photonics and superconductivity in one CMOS-compatible substrate.

*Speaker

Granular Aluminum for hybrid Germanium devices

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Planar germanium quantum wells have emerged as a promising platform for superconductor-semiconductor devices. The combination of long coherence times, strong spin-orbit interaction, and robust proximity effect positions germanium uniquely for complex hybrid architectures. However, devices such as Andreev spin qubits require Zeeman splittings in the order of several GHz-a significant challenge in strained germanium quantum wells due to the small in-plane g-factors. We overcome this bottleneck by inducing superconductivity using granular aluminum (GrAl), which allows Zeeman splitting beyond 9 GHz for out-of-plane magnetic fields. We report an induced hard gap of 270 μeV and out-of-plane magnetic field resilience exceeding 200 mT using wide superconducting leads (500 nm to _˜1 μm). Remarkably, similar field resilience is obtained even for contacts up to 3 μm in width. Furthermore, by tuning the aluminum-to-oxygen ratio, we demonstrate tunability over the field resilience in the proximized germanium, providing a promising pathway to optimize superconducting properties. The use of GrAl enables a relatively simple fabrication process through room-temperature electron beam evaporation of aluminum in an oxygen atmosphere, without the need for annealing, etching, or cryogenic deposition.

*Speaker

Epitaxial control of group IV quantum material heterostructures

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Achieving high-quality, defect-free epitaxial interfaces between superconductor and semiconductor materials is essential to improve transparency of Josephson junctions and the robustness of superconducting qubits. To this end, integrating epitaxial Aluminum (Al) superconducting contacts grown by molecular beam epitaxy (MBE) on InAs/InGaAs QWs improved the performance of gatemon qubits (1). Exploring novel epitaxial superconductor materials is of paramount importance to enhance the quantum device performance. In this work, we will discuss the epitaxial growth of superconducting Tin (Sn) in the body-centered tetragonal β-phase (β-Sn) and the interface quality with group IV quantum materials to pave the way for their use in superconducting qubits. β-Sn has a critical temperature Tc=3.7 K that is higher than Al (Tc = 1.2 K), thus resulting in a larger superconducting gap, while also offering enhanced resilience to external magnetic fields. The use of β-Sn in superconducting quantum devices has been demonstrated with III-V semiconductors (2), however similar studies on group IV materials are still missing.

In the presentation, we will show the epitaxial growth of β-Sn on a Ge (100) wafer achieved using a cryogenic MBE system. A detailed correlation between morphology, dislocations, grain sizes, and strain of the β-Sn samples will be discussed by combining SEM, Raman, XRD, and TEM to highlight the key role of pre-growth surface engineering on the structural quality of epitaxial β-Sn. Magnetotransport measurements performed at

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*Speaker

Field-effect giant modulation of photon-mediated heat transport on the InAs-on-Insulator platform

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In cryogenic solid-state devices, thermal management is a crucial issue, as it prevents unwanted excitations from disrupting coherence and performance. Among various thermal management architectures, photon-mediated heat transport is an effective and versatile framework (1).
Previous works demonstrated efficient photon-mediated heat transfer between resistive metallic reservoirs linked by superconducting lines. Heat is transferred via Johnson-Nyquist black-body radiation exchanged between the reservoirs. This exchange is tuned by adjusting the impedance of components integrated into the lines. So far, this has been achieved with SQUIDs pierced by magnetic fields or Coulomb blockade on gate-controlled islands, with temperature modulations of a few millikelvins.

This study presents a novel application of photonic heat transport in super-semiconductor hybrid systems. We have developed the InAs-on-Insulator (InAsOI) platform, featuring the growth of an indium arsenide (InAs) layer on an insulating indium aluminium arsenide (InAlAs) buffer, integrated with aluminium-based superconducting electrodes (2). InAsOI enables the investigation of previously uncharacterised phenomena of heat transport in hybrid systems, effectively overcoming the limitations of entirely metallic architectures. Importantly, the InAsOI platform supports gate-tunable supercurrent densities of high magnitude, while also offering simplified and scalable configurations (2,3). Moreover, the platform demonstrates low electron-phonon thermal coupling, which is essential for achieving greater thermal isolation from the environment (4), a key requirement for larger temperature variations.

The experimental setup under study includes two InAsOI reservoirs connected via aluminium superconductive pathways, which incorporate InAsOI-Al gated weak links, specifically Josephson Field-Effect Transistors (JoFETs), along with capacitors for electrical isolation. The JoFET acts as a gate-tunable impedance, serving as an electrically controlled thermal modulator. This modulation causes temperature variations in the reservoirs exceeding 40 millikelvin, representing a tenfold improvement over previous technologies. Such precise control over the thermal dynamics of cryogenic systems demonstrates robustness across a broad range of electronic and environmental temperatures. The results highlight the potential of the hybrid InAsOI platform

*Speaker

in advancing the understanding of photonic heat transport, utilizing the superior thermal properties of semiconductors while exploring interactions with unique hybrid platform features, such as gate-tunable superconductivity. Ongoing progress in this technology is expected to facilitate effective non-galvanic and low-disturbance management of thermal flux in mesoscopic solid-state systems.

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Behavioral and Physics-Based Modeling of Josephson Field-Effect Transistors (JoFETs)

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The Josephson Field Effect Transistor (JoFET) is a versatile building block for ultra-low-power and high-energy-efficiency classical and quantum electronics. In a JoFET, the superconducting current is controlled by electrostatic gate voltage. Among various material platforms, graphene-channel JoFETs have emerged as promising candidates for superconducting hybrid integration owing to their gate-tunable transport properties (1), (2) and compatibility with scalable device fabrication (3).
Accurate modeling of JoFETs is essential for circuit-level design and understanding the physical mechanisms governing device operation (4). Here, we report two complementary modeling approaches for a graphene channel JoFET with dimensions of channel width 20 μm and length 350 nm. These models have been implemented in commercial and open-source circuit simulators, namely Keysight ADS and Ngspice.

1. Behavioral Model

The behavioral model provides a compact empirical description of the nonlinear current–voltage (I–V) characteristics by representing the gate-dependent superconducting region through a simple power-law relation. This simple empirical relation effectively reproduces the nonlinear I–V behavior observed experimentally, providing a compact lookup table-based representation of JoFET characteristics.

2. Physics-Based Model

The physics-based model links JoFET behavior to the electronic transport in the graphene channel, capturing the gate-voltage (V_g) dependence of both normal-state resistance (R_N) and critical current (I_C). It accounts for carrier density modulation in the graphene channel, including contributions from residual doping and quantum capacitance.

The superconducting critical current can be connected to the normal-state resistance through a modified Ambegaokar–Baratoff relation, reflecting the effects of junction transparency and the induced superconducting gap.

Finally, to reproduce the I–V characteristics of the device, the model is embedded within a

*Speaker

gate-dependent resistively and capacitively shunted junction (RCSJ) framework. This allowed reproducing the full I–V behavior across gate voltages, matching experimental data with high fidelity.

Overall, the combined behavioral and physics-based models comprehensively describe the JoFET's gate-tunable superconducting transport, providing deeper insight into device operation and paving the way for the development of a practical compact model.

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Non-Hermitian Skin Effect and Electronic Nonlocal Transport

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Open quantum systems governed by non-Hermitian effective Hamiltonians have recently emerged as a new frontier in condensed matter physics, revealing unconventional phenomena that remain concealed in Hermitian descriptions. Among these, the non-Hermitian skin effect (NHSE), where eigenstates localize at system boundaries, has attracted intense theoretical and experimental interest in several fields, including photonics and electronic devices. However, its experimental signatures in the latter have not been described so far. In this work, we demonstrate that the NHSE naturally arises in a realistic hybrid device: a Rashba nanowire strongly coupled to a ferromagnetic lead.

We show that the NHSE can be probed through transport spectroscopy. While the local conductance remains symmetric, the non-local conductance becomes markedly non-reciprocal. We account for this behavior using both conventional transport arguments and the framework of non-Hermitian physics. Furthermore, we explain why exceptional points, points in parameter space where the effective Hamiltonian is not diagonalizable, shift in parameter space when transitioning from periodic to open boundary condition. This phenomenon has been observed in similar systems but so far not explained.

These findings establish hybrid ferromagnetic-semiconductor nanowires as a platform to explore non-Hermitian physics through transport spectroscopy.

*Speaker

Towards Calorymetric Detection of Microwave Photons by Means of Proximity Effect

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Calorimetric single microwave photon detection remains one of the key challenges in modern experimental physics, with direct implications for astronomy and emerging quantum technologies. The extremely small photon energy in the microwave regime makes reliable detection particularly difficult. This study proposes and analyzes a broadband calorimetric detector based on the superconducting proximity effect. In a normal metal–superconductor (SN) hybrid structure, the proximity effect suppresses the metal's density of states for energies below the superconducting gap. This suppression reduces the electronic heat capacity, thereby enhancing the temperature rise following photon absorption beyond the electron–phonon noise limit. Our goal is to develop a comprehensive theoretical description of the SN system using the Usadel and master equations. Particular attention is devoted to the physical bounds on the achievable signal-to-noise ratio and detection efficiency. Numerical simulations will subsequently be used to identify optimal material and geometric parameters for device fabrication.

*Speaker

The ultra-short Josephson junction

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Planar Josephson junctions offer a platform for realizing topological superconductivity with minimal magnetic fields, a key advantage over nanowire-based proposals.
This is enabled by the flux tunability of the Andreev bound states and the short-junction regime, where the distance between the two superconductors is much smaller than the superconducting coherence length.
In this talk, I will introduce the iultra-short superconducting-normal-superconductor Josephson junction: a tunnel junction that proximitizes a two-dimensional electron gas.
I will show that this device hosts a minimal number of Andreev modes and is in the short-junction limit, a consequence of the distance between the two proximitized regions in the 2DEG.
I will demonstrate how ultra-short junctions optimize the design of Majorana zero modes, and enable anomalously large momentum transfer from the superconducting condensate to the quasi-particles they emit.

*Speaker

The influence of thermal current fluctuations on the apparent increase in critical current from the magnetic field.

Ruslan Yakubovych * [1], Sergey Frolov *

[2]

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Recent literature attributes unusual magnetic-field dependences of the critical current, including apparent increases with field, to exotic superconductivity. We examine a more prosaic mechanism: fluctuation driven premature switching in Josephson junctions operated in the switching regime. Using the classical RCSJ model, we analyze switching distributions across three operating conditions: overdamped, underdumped, and quasi-regime, while varying temperature and other noise sources. We also consider the direct inclusion of the resistance or capacitance peak for a phenomenological attempt to description of the effect. Our results show that fluctuations allow the critical current to be changed by including the peak quite dramatically.

*Speaker

Development of gate-tunable nanowire Josephson junctions using novel strategies

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This work reports on novel strategies for building gate tunable nanowire Josephson junctions aimed at forming the building blocks of quantum circuits. We look for material combinations and designs that provide high superconducting current, hard superconducting gap, magnetic field resilience and tunability of the supercurrent flowing throught the weak link. We propose to use Sn as an alternative superconductor to Al in shadow defined hybrid InAs nanowire junctions. We demonstrate large critical currents up to 500 nA and magnetic field resilience up to 1 T. Alernatively, we propose the use of parallel nanowires as weak links of an Al/InAs based Josephson junction to increase the critical current flowing between the two contacts while maintaining gate tunability. Finally, we will discuss the scalability of such systems using III-V 2DEGs covered with Sn thin films.

*Speaker

Tuning Schottky barrier transparency in CoSi2/Si/CoSi2 junctions fabricated by using Ga focused ion beam

Juan Galván Paz * [1], Tosson Elalaily [1], Yuvraj Chaudhry [1], Weijun Zeng [1], Ekaterina Mukhanova [1], Elica Anne Heredia [2], Chun-Wei Wu [2], Ilari Lilja [1], Tomas Capiten [1], Matias Perkiö [1], Stanislav Khaldeev [1], Shubhadip Moulick [1], Juhn-Jong Lin [2], Sheng-Shiuan Yeh [2], Jere Mäkinen [1], Pertti Hakonen [1]

[1] Aalto University School of Science – Finland
[2] National Yang Ming Chiao Tung University [Taipei] – Taiwan

Silicon (Si), due to its abundance, cost-effectiveness, and scalability, has revolutionized the modern electronics industry. It enables the fabrication of integrated circuits (ICs), transistors, and microchips, all essential components of a wide range of electronic devices. Furthermore, its ability to form a stable silicon dioxide (SiO) layer makes it ideal for developing metal-oxide-semiconductor field-effect transistors (MOSFETs), which are the fundamental building blocks of digital electronics. Superconducting silicides, such as cobalt disilicide (CoSi), are compounds composed of silicon and transition metals that exhibit superconductivity at low temperatures. These materials are highly promising for advancing quantum computing and superconducting electronics due to their unique combination of superconducting properties and compatibility with silicon-based technology. Silicide/Si platforms are particularly attractive candidates for realizing scalable superconducting Josephson field-effect transistors (JOFETs). However, a major challenge lies in the large Schottky barrier at the silicide/Si interface, which suppresses Cooper pair tunneling into silicon. Overcoming this barrier requires precise doping of the silicon to enable gate-tunable charge transport, preferably through a localized doping technique. In this work, we etched a 100 nm-wide trench into a CoSi transmission line using a gallium (Ga) focused ion beam (FIB), forming CoSi/Si/CoSi junctions. The use of high-energy (30 keV) Ga ions during trench milling not only defines the junction but also introduces Ga dopants into the exposed Si region. We demonstrate that varying the Ga ion dose enables control over the doping level in the Si region, thereby modulating the transparency of the Schottky barrier.

*Speaker

Unconventional magnetism and spin-orbit coupling in superconducting hybrid systems

Tim Kokkeler * [1]

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The field of superconducting spintronics has recently evolved from a focus on the interplay of superconductivity with ferromagnetism and various types of spin-orbit coupling, to include also unconventional types of magnetism such as altermagnetism and p-wave magnetism. Like spin-orbit coupling, these unconventional magnets can either be a bulk phenomenon or appear in a two dimensional material or interface, and they have a momentum-dependent spin-splitting that vanishes after averaging over the Fermi surface. However, unlike spin-orbit coupling, the underlying mechanisms break time-reversal symmetry. As discussed in this talk, this difference leads to qualitatively different transport responses in hybrid structures, both in equilibrium and out-of-equilibrium. To show this, first the transport equations for unconventional magnets with superconductivity are discussed, including the influence of the spin-dependent diffusion constant on Cooper pairs and an unconventional Larmor precession. Then, several effects are presented that are unique to hybrid systems with superconductivity and unconventional magnetism, and they are compared with effects that appear due to the interplay of superconductivity with spin-orbit coupling.

*Speaker

Switching dynamics of InAs/Al superconducting nanocircuits

Martin Berke * [1], Péter Makk [1]

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Integrated circuits with superconducting building blocks would have several benefits, such as high speed and low power consumption. In recent years, surprisingly, control of the supercurrent with voltage applied on a nearby electrode in all-metallic materials has been observed. This phenomenon can be used to fabricate gate-controlled transistors from superconducting materials, analogous to the field effect transistors. The suppression of the supercurrent was investigated in several materials, however there is no scientific consensus on the microscopical explanation (1-2).
We studied gate tuneable supercurrents in Al superconducting shells epitaxially grown on the top of InAs nanowires (3). We have investigated the properties of such switches using switching current distributions and shown the importance of fluctuations using noise measurements (4,5). We have also examined the switching dynamics of the investigated nanowire and analysed the possible switching speed of our device using both broadband pulsed measurements and by coupling them to superconducting resonators (6,7).

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*Speaker

Quantum Kinetic Uncertainty Relations in Mesoscopic Conductors at Strong Coupling

Gianmichele Blasi [1], Ricard Ravell * [2], Mykhailo Moskalets [3], Rosa López [2], Géraldine Haack [1]

[1] UNIGE – Switzerland
[2] IFISC – Spain
[3] NTU Kharkiv Polytechnic Institute – Ukraine

Kinetic Uncertainty Relations (KURs) establish quantum transport precision limits by linking signal-to-noise ratio (SNR) to the system's dynamical activity, valid in the weak-coupling regime where particle-like transport dominates. At strong coupling, quantum coherence challenges the validity of KURs and questions the meaning of the concept of activity itself. Here, we introduce a generalized dynamical activity valid at arbitrary coupling and derive a steady-state quantum KUR (QKUR) expressed in terms of this generalized activity. Explicit expressions are obtained within Green's function and Landauer-Büttiker formalisms. This QKUR ensures that uncertainty relations are valid across all coupling strengths, offering a general framework for out-of-equilibrium quantum transport precision analysis. We illustrate these concepts for paradigmatic quantum-coherent mesoscopic devices: a single quantum channel pinched by a quantum point contact and open single- and double-quantum dot systems.

*Speaker

Superstrong Dynamics and Directional Emission of a Giant Atom in a Structured Photonic Environment

Léo Peyruchat * [1,2], Vincent Jouanny [2], Marco Scigliuzzo [3], Alberto Mercurio [4], Enrico Di Benedetto [5], De Bernardis Daniele [6], Davide Sbroggio [2], Simone Frasca [2], Vincenzo Savona [7], Francesco Ciccarello [8], Pasquale Scarlino [2]

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[4] Laboratory of Theoretical Physics of Nanosystems (LTPN), Institute of Physics, École Polytechnique Fédérale de Lausanne (EPFL) – Switzerland

[5] Università degli studi di Palermo - University of Palermo – Italy

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[7] Laboratory of Theoretical Physics of Nanosystems (LTPN), Institute of Physics, École Polytechnique Fédérale de Lausanne (EPFL) – Lausanne, Switzerland

[8] NEST, Istituto Nanoscienze-CNR and Dipartimento di Fisica e Chimica, Università degli Studi di Palermo – Palermo, Italy

Quantum emitters coupled to waveguides with nonlinear dispersion show rich quantum dynamics with the promise of implementing non-trivial non-Markovian quantum models. Recent advances in engineered photonic environments now allow the realization of discrete-site waveguides with tailored dispersion, yet most implementations of waveguide QED remain limited to a local qubit-waveguide coupling. Here, we study a transmon qubit non-locally coupled to a high-impedance coupled cavity array (CCA), thus implementing a giant atom in a structured photonic environment. The non-local coupling produces interference with the CCA modes, selectively enhancing interaction with even and long-wavelength modes, while suppressing coupling to odd and short-wavelength modes. For a subset of symmetric, long-wavelength modes, we reach the superstrong coupling regime. In this regime, measurements of the atomic participation ratio reveal strongly hybridized eigenmodes on a par with a strongly reduced qubit participation at the frequency of maximum hybridization with the qubit, in agreement with theory. Time-domain measurements of the qubit dynamics show clear deviations from the single-mode Jaynes-Cummings model, marked by the emergence of mode–mode interactions. By breaking spatial inversion symmetry of the CCA, the qubit seeds dressed eigenmodes confined to either the right or left of the qubit, which we exploit to implement and characterize a directional photon-emission protocol. These results demonstrate precise control over multimode light–matter interaction in a structured photonic environment

*Speaker

Josephson anomalous vortices and rotary invariants

Dan Crawford * [1], Stefan Ilić [1], Pauli Virtanen [1], Tero Heikkilä [1]

[1] Department of Physics and Nanoscience Center, University of Jyväskylä – Finland

We show that current vortices, related to odd-frequency triplet superconductivity, appear in Josephson junctions where the barrier is a weak ferromagnet with strong spin-orbit coupling. These vortices are related to textures in the superconducting pairing amplitudes. By symmetry analysis we show that there is an additional term - a rotary invariant - in the superconducting free energy, even when the Lifshitz invariant vanishes. We show via microscopic simulations that the size, shape, and position if these vortices can be controlled by manipulating spin-orbit coupling in the weak link, via gates. We suggest that these vortices could be detected by scanning magnetometry techniques.

*Speaker

Transmon qubit using Sn as a junction superconductor

Sergey Frolov * [1]

[1] University of Pittsburgh – United States

Superconductor qubits typically use aluminum-aluminum oxide tunnel junctions to provide the non-linear inductance. Junctions with semiconductor barriers make it possible to vary the superconductor material and explore beyond aluminum. We use InAs semiconductor nanowires coated with thin superconducting shells of beta-Sn to realize transmon qubits. By tuning the Josephson energy with a gate voltage, we adjust the qubit frequency over a range of 3 GHz. The longest energy relaxation time, T1 = 27 microseconds, is obtained at the lowest qubit frequencies, while the longest echo dephasing time, T2 = 1.8 microseconds, is achieved at higher frequencies. We assess the possible factors limiting coherence times in these devices and discuss steps to enhance performance through improvements in materials fabrication and circuit design.

*Speaker

February 6, 2026

Poster presentations

2D van der Waals Josephson devices

Mandar M. Deshmukh * [1]

[1] Tata Institute of Fundamental Research – India

I will discuss two classes of Josephson devices. First, proximitized graphene-based Josephson junctions that are gate tunable. The graphene Josephson FET enables a quantum-noise-limited parametric amplifier with performance comparable to the best discrete amplifiers in this class (1). One can realize extremely sensitive and fast bolometers (2) – useful for dark matter search, among other applications. Second, twisted van der Waals heterostructures based on the high-temperature superconductor Bi2Sr2CaCu2O8+δ enable the realization of a high-temperature Josephson diode (3) for the first time. Such Josephson diodes offer an opportunity to realize new devices at liquid nitrogen temperatures.
While opportunities abound with vdW JJs, the challenge of scalability must be overcome to translate them into real-world devices.

(1) "Quantum-noise-limited microwave amplification using a graphene Josephson junction" Joydip Sarkar et al. , Nature Nanotechnology 17, 1147 (2022).

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(3) "High-temperature Josephson diode," Sanat Ghosh et al. Nature Materials 23, 612 (2024).

*Speaker

Proximitized topological edge channels for bound states and non-reciprocal transport

Niccolò Traverso Ziani * [1]

[1] Dipartimento di Fisica, Università di Genova – Italy

Hybrid systems combining topological edge channels and s-wave superconductors have emerged as promising platforms for superconducting spintronics and topologically protected quantum computation (1). Recent advances have expanded this landscape through the engineering of constrictions between helical edges (2), which-when proximitized-are predicted to host exotic quasiparticles such as Majorana bound states (3), Z parafermions (4), and equal-spin Cooper pairs (5). Within this framework, we demonstrate that coupling topological edge channels can induce multiple topological quantum phase transitions (6). Remarkably, these transitions can give rise to isolated Majorana bound states even in systems that, without constrictions, behave as nodal superconductors (7), revealing a novel route to topological bound states. Furthermore, we explore how constrictions influence superconducting non-reciprocal transport. Specifically, we show that the rectification coefficient of superconducting diodes in proximitized topological structures is highly sensitive to edge reconstruction, enabling diode-like behavior even in the absence of external magnetic fields or magnetic ordering (8).

(1) B. Weber, et al.
Title: 2024 Roadmap on 2D Topological Insulators
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(2) J. Strunz, J. Wiedenmann, C. Fleckenstein, L. Lunczer, W. Beugeling, V. L. Müller, P. Shekhar, N. Traverso Ziani, S. Shamim, J. Kleinlein, H. Buhmann, B. Trauzettel, L. W. Molenkamp
Title: Interacting Topological Edge Channels
Nat. Phys. 16, 83–88 (2020)
(3) C. Fleckenstein, N. Traverso Ziani, A. Calzona, M. Sassetti, B. Trauzettel
Title: Formation and Detection of Majorana Modes in Quantum Spin Hall Trenches
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(4) C. Fleckenstein, N. Traverso Ziani, B. Trauzettel
Title: Z Parafermions in Weakly Interacting Superconducting Constrictions at the Helical Edge of Quantum Spin Hall Insulators
Phys. Rev. Lett. 122, 066801 (2019)
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Title: Conductance Signatures of Odd-Frequency Superconductivity in Quantum Spin Hall Systems Using a Quantum Point Contact
Phys. Rev. B 97, 134523 (2018)
(6) S. Traverso, M. Sassetti, N. Traverso Ziani
Title: Emerging Topological Bound States in Haldane Model Zigzag Nanoribbons
npj Quantum Mater. 9, 9 (2024)

*Speaker

(7) S. Traverso, N. Traverso Ziani, M. Sassetti, F. Dominguez
Title: Confinement-Induced Majorana Modes in a Nodal Topological Superconductor
arXiv preprint arXiv:2407.06925 (2024)
(8) S. Fracassi, S. Traverso, M. Carrega, S. Heun, M. Sassetti,N. Traverso Ziani
Title: Study on Superconducting Diode Effect and Edge Reconstruction in Topological Josephson Junctions *(Manuscript in preparation, 2025)*

Phase Controlled Topological Superconductivity

Yuval Oreg * [1]

[1] Weizmann Institute for Science – Faculty of Condensed matter physics in The Weizmann Institute of Science POB 26 Rehovot 76100, Israel, Israel

This talk will explore practical methods for stabilizing topological superconductors using one- and two-dimensional arrays of Josephson junctions. The key technique is order parameter phase engineering in systems that have different Fermi velocities for different spin branches. By adjusting the superconducting phase differences through minute magnetic fields or small bias currents, these arrays can be driven into and maintained within topological regimes. I will outline the families of materials with the desired properties and introduce simple theoretical models and experimentally realistic geometries, highlighting the key control parameters and describing the expected signatures of the topological phase.

*Speaker

List of participants

- Araya Day Isidora
- Assali Simone
- Berke Martin
- Borgongino Laura
- Bretheau Landry
- Casal Iglesias Ignacio
- Castillo Guerrero Adan
- Catalano Sara
- Chiodi Francesca
- Clara Galante
- Crawford Dan
- Cécile Naud
- Deshmukh Mandar
- Fabris Giorgio
- Falthansl-Scheinecker Paul
- Francesco Maraspini
- Frolov Sergey
- Fugl Emma
- Gallagher Ciara
- Galván Paz Juan
- Gamaethige Shanuka
- Generalov Andrey
- Giacoia Mauro
- Gul Yilmaz
- Heikkilä Tero

- Hocevar Moïra
- Höfer Johannes
- Horodecki Michal
- Janowicz Paulina
- Kapoor Pranjal
- Khaleefah Saqar
- Khan Barka
- Kokkeler Tim
- Kowalczyk Mateusz
- Kozin Valerii
- Lefloch François
- Lehtisalo Markus
- Lemaître Aristide
- Lind Erik
- Liu Yu
- Lobo Francisco
- Lugstein Alois
- Manesco Antonio
- Mestre Tora Alexandra
- Meyer Julia
- Morassi Martina
- Matteo Pioldi
- Nygård Jesper
- Olausson Louise
- Oreg Yuval
- Paghi Alessandro
- Palmstrom Chris
- Paradiso Nicola
- Payá Carlos
- Peter Makk
- Peyruchat Léo
- Plissard Sébastien

- Prada Elsa
- Pyrchla Krzysztof
- Rana Deepti
- Ravell Ricard
- Refael Gil
- Renard Julien
- Samanta Dibyendu
- San-Jose Pablo
- Sarkar Joydip
- Scherübl Zoltán
- Schönenberger Christian
- Shah Devashish
- Sidorczak Pawel
- Sistani Masiar
- Steffensen Gorm Ole
- Su Yao
- Taskinen Jani
- Traverso Ziani Niccolò
- Turmel Mathieu
- Van Waveren Aiken
- Yakubovych Ruslan
- Zhang Yining
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