JYVÄSKYLÄN YLIOPISTO

Institute

FINNISH QUANTUM DAYS 2026

POSTER ABSTRACT BOOK

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Contents

Track: Quantum Computing, Algorithms & Software

Number of Posters: 14

Geodesic-based optimal control for quantum gates in superconducting qubits

P001

Adonai da Silva
VTT

Track: Quantum Computing, Algorithms & Software

Abstract

In earlier works: [arXiv:2503.09593] and [arXiv:2601.10446], it was presented a geodesic-based optimal control method for implementing one- and two-qubit gates in a general, system-independent framework. We now extend this approach to a more realistic description of superconducting qubits used in current VTT quantum processors, specifically tailored to address the leakage problem.

A Socio-Technical Decision Framework for Guiding the Evolution of Quantum HPC Software Stacks

P002

Ronja Heikkinen
University of Jyväskylä

Track: Quantum Computing, Algorithms & Software

Abstract

Quantum computing environments are composed of heterogeneous layers spanning hardware, software development kits, and applications. Practitioners curating these environments face a fragmented, rapidly evolving landscape with few principled guides for navigation, where components create combinatorial configuration complexity and prevent the formation of stable development environments. This poster presents a framework for evaluating quantum computing environment choices through a socio-technical lens. The framework introduces three analytical constructs. Gravity wells and their properties of workflow specialization, technology entrenchment, and ecosystem convergence pressure, which characterizes how certain technologies and structural conditions exert increasing pull on surrounding environment choices. Components can be identified as gravity wells through how they show the gravity well properties. Socio-technical desiderata, including operational and governance transparency, knowledge and skill portability, avoidance of irreversible constraints, and preservation of experimentation articulate the normative goals against which the gravity wells can be evaluated. The framework design includes scoring practices to make the evaluation procedure more structured and a better fit to the user's needs. Together, these constructs support practitioners in making deliberate, context-aware environment choices that preserve architectural flexibility and support the evolutionary development of the field. We demonstrate the framework's use in the case of developing a software stack for quantum high-performance computing. We apply the scoring method of desiderata gap scoring, which helps prioritize roadmap and find strategically misaligned nodes. The framework advances both the theory of quantum ecosystems and the practical guidance available to organizations navigating the current quantum computing landscape.

Quantum-assisted Quadrature Rule for Insurance Payoff Models

P003

Cristian Galvis Florez
Aalto University

Track: Quantum Computing, Algorithms & Software

Abstract

We provide a quantum solution for insurance-related numerical integration problems arising in financial and actuarial modeling. We first formulate the problem within the framework of classical Gaussian process quadrature (GPQ). To reduce the computational cost of classical GPQ, we adopt a reduced-rank Hilbert-space Gaussian process quadrature approach. Building on this classical formulation, we propose a quantum algorithm that maps the Hilbert-space GPQ rule to a fault-tolerant gate-based quantum framework. The resulting method provides a more efficient framework for evaluating insurance payoffs, offering a polynomial computational advantage over the corresponding classical approach. Through numerical simulations of various insurance payoff models, we demonstrate that the proposed method closely matches classical estimates, indicating the practical effectiveness of the algorithm.

NISQ-friendly Coined Quantum Walk for Chaos-based Cryptographic Applications

P004

Natalie Gibson
Aalto University

Track: Quantum Computing, Algorithms & Software

Abstract

We present a novel lackadaisical alternating quantum walk (LAQW) algorithm whose circuit depth scales as $\mathcal{O}(n^2 + t)$ for a $n \times n$ lattice over t time steps. We show that this is a significant depth reduction compared to the existing controlled alternating quantum walk (CAQW) model, which has a circuit depth that scales as $\mathcal{O}(n^2 t)$ (Li et al., 2017, arXiv:1707.07389). This makes the implementation of the LAQW viable for Noisy Intermediate-scale Quantum (NISQ) devices. We then showcase the applicability of the LAQW algorithm by proposing a chaos-based symmetric-key generation scheme. Our approach uses the LAQW as a quantum entropy source from which reproducible random bitstring sequences are generated using the underlying probability distribution and subsequent post-processing methods. We provide a comprehensive evaluation of the LAQW algorithm and demonstrate the reproducibility of 128-bit keys under simulated quantum noise provided by IBM's FakeTorino backend. A direct comparison with the CAQW model, which has been used in image encryption and hash function schemes (Li et al., 2017, arXiv:1707.07389; Abd EL-Latif et al., 2020, ScienceDirect; Abd El-Latif, Abd El-Atty, and Venegas-Andraca, 2020, ScienceDirect), highlights the potential and usefulness of the LAQW model in cryptographic applications.

Probing Quantum Error Correction on Superconducting Hardware: A Device-Specific Benchmarking Study

P005

Ashutosh Kumar
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Track: Quantum Computing, Algorithms & Software

Abstract

Quantum error correction (QEC) is the key technology required to build reliable, fault-tolerant quantum computers. While theoretical frameworks for QEC are well established, their performance on real hardware is heavily influenced by device-specific noise properties that standard benchmarking metrics do not capture. This work presents an ongoing experimental study of QEC performance on Finnish superconducting quantum processors. We implement rotated surface codes and repetition codes across multiple code distances and measure logical error rates directly on hardware. A central motivation is that near-term superconducting devices exhibit spatially uneven qubit quality, where a subset of qubits has significantly higher error rates than the device average, and correlated errors between neighbouring qubits violate assumptions of standard decoders. To characterise these effects, we construct hardware-calibrated detector error models (DEMs) fitted directly to experimental syndrome data, rather than relying on idealised noise assumptions. Preliminary work focuses on the experimental circuit design, transpilation to native gate sets, and establishing baseline logical error rate measurements. These results are compared against classical simulations run on the LUMI supercomputer, enabling a systematic assessment of where standard noise models fail to reproduce hardware behaviour. The fitted DEMs will subsequently guide the design of QEC codes and decoding strategies tailored to the specific error structure of each device.

Learning Quantum Phases from Basis-Dependent Sparsity

P006

Clemens Lindner
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Track: Quantum Computing, Algorithms & Software

Abstract

We introduce an inverse participation ratio (IPR)–based approach for classifying quantum states through their basis-dependent sparsity. The key idea is that quantum states can appear localized in some bases and delocalized in others, and that this behaviour changes across different physical regimes. By evaluating IPRs in a set of chosen bases, we construct a kernel that captures these patterns. We show that this approach enables phase classification from sparsity signatures alone and that the resulting kernel retains a clear separation between different regimes as the system size increases. We demonstrate these properties numerically on representative quantum many-body systems. This work highlights basis-dependent sparsity as a simple and physically meaningful feature for quantum machine learning.

Identifiability Transitions in Classical and Quantum Fourier Signal Encodings

P007

Mikko Mäkitalo
Oulun yliopisto

Track: Quantum Computing, Algorithms & Software

Abstract

The identifiability and reconstructibility of the parameters of quantum circuits is an inversion problem that arises when the signal to be encoded into the circuit is known. In this study, we study the encoding of Fourier signals consisting of phase-shifted sinusoidal components into quantum circuits. As the number of components increases, the signal becomes more complex due to the effects of interference, which affects the identifiability of the quantum circuit parameter values. We evaluate reconstructability performance using neural network (NN), hybrid (NN + BFGS) optimization, and quantum measurement-based methods. We analyze the identifiability of the signals using three metrics (error, Fisher, and Jacobian). As the order of the Fourier signal increases, we observe a transition regime where the recoverability of the quantum circuit parameters shifts from easily identifiable to ill-predictable. This transition is driven by the nonlinear interference of the Fourier signals, which reduces effective parameter distinguishability. The effect is significantly more pronounced in quantum measurement, where the projection onto classical results leads to additional information reduction. As a result, quantum feature-based inference shows an earlier and more pronounced degradation compared to the classical methods, even with an increased number of quantum circuit shots. In this study, we observed that quantum circuit measurements have a reducing effect on the identifiability of information and parameters, a phase transition that appears at lower Fourier signal degrees in comparison to the classical ones. From an information-theoretic perspective, the loss of identifiability corresponds to the increasing indistinguishability between parameter configurations, implicating a connection to information security.

Solving Quantum Many-Body Problems with Analog Devices

P008

Vinícius Mohr
ETH Zurich

Track: Quantum Computing, Algorithms & Software

Abstract

When addressing quantum many-body problems, variational methods applied to parametrized ansätze have proven highly effective in capturing ground state properties. In this work, we seek to expand the range of viable models by incorporating analogue devices that are challenging to simulate classically, leveraging the Variational Monte Carlo (VMC) framework to efficiently optimize these systems.

P009

L^2-Anticoncentration and Fourier Visibility in Two-Local IQP Born Machines

Väinö Mehtola
VTT

Track: Quantum Computing, Algorithms & Software

Abstract

IQP Born machines have been proposed as candidates for a "train classically, deploy on quantum hardware" approach to quantum generative modelling, motivating the search for architectures that might combine sampling-hardness potential with trainability. We study graph-structured IQP Born machines with all one-body phase generators and two-body generators on graph edges, using the critical-rank framework to relate ensemble-averaged collision-probability (L^2) anticoncentration to the visibility of low-weight Fourier modes at uniformly random initialization. For a graph G, these diagnostics are governed by the closed-neighborhood rank $r_G(A)=|N_G[A]|$ and the collision sum $S(G)=\sum_{A\subseteq V}2^{-r_G(A)}$. We prove an exact half-shell domination-defect criterion for bounded $S(G)$ and for convergence to its asymptotic graph-IQP floor, $2+o(1)$, showing why logarithmic maximum degree alone is insufficient: rare subsets with small closed neighborhoods can dominate through insufficient or redundant exposure. Together with $\Delta(G)=O(\log n)$, this yields an architecture-level coexistence criterion for L^2 anticoncentration and inverse-polynomial visibility of every fixed-low-weight mode. Within the logarithmic-degree regime, we obtain the sharp random-regular boundedness threshold $d\geq\log_2 n-O(1)$ and the Newman–Watts-type additive-shortcut boundedness threshold $s=2$, and establish further coexistence regimes for hypercubes, an existential spectral-expander sequence, uniform shortcuts, sparsely rewired Watts–Strogatz graphs, and homogeneous block models. The results are ensemble-averaged initialization diagnostics, not guarantees of optimization, generalization, or sampling hardness after training.

P010

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Track: Quantum Computing, Algorithms & Software

Abstract

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Noise Adaptive SPAM Purification for large scale QPUs

P011

Srivathsan Srinivasan
VTT Technical Research Institute of Finland
Track: Quantum Computing, Algorithms & Software

Abstract

State preparation and measurement (SPAM) errors on current quantum processors set a fidelity floor that cannot be addressed by gate-level quantum error correction, and the cost of mitigating these errors has grown substantially with device size. Existing purification protocols that suppress SPAM noise through ancillary qubits and collective CNOT gates \cite{kim_static_2024} treat the ancillas as sacrificial resources, which makes their application to full-register initialization on large processors expensive: every purified qubit requires one or more qubits to be consumed. Here we introduce a noise-adaptive SPAM purification scheme designed for large-scale QPU initialization, in which no qubit is sacrificed and the protocol maps qubits to ancillas based on daily calibration data and explores the trade off regime between the SPAM protocol fidelity and fraction of shots discarded. Building on this, we formulate the choice of which qubit patches to purify with two and one ancillas, which to herald, and how to route the necessary two-qubit gates as a calibration-driven optimization over the device's connectivity graph, solvable at compile time. We demonstrate the full pipeline by preparing a fifteen-qubit GHZ state on VTT Q50 53-qubit superconducting QPU, comparing acceptance rates and population fidelities to the heralding baseline, and showing that the adaptive scheme outperforms both uniform purification and plain heralding.

Quantum DevOps: Making Quantum Software Reproducible Across Providers

P012

Jouni Peltonen
University of Jyväskylä
Track: Quantum Computing, Algorithms & Software

Abstract

Quantum programs are rarely executed in the form developers write them. Before execution, circuits are transformed by compiler and provider toolchains that evolve independently of the application source code: SDK updates, transpiler changes, backend recalibrations, and provider integration layers can silently alter the circuit that actually runs. This undermines reproducibility, cross-provider comparability, and trust in experimental results — precisely the properties that classical software engineering addresses with DevOps practices. This work argues that quantum software needs DevOps-style infrastructure — provenance, drift detection, and pipeline automation — to be engineerable across heterogeneous quantum providers. We present three complementary contributions. First, a provenance framework built around a unified API across quantum providers records the complete software and execution context of quantum runs behind a single interface, enabling observability and retrospective audit regardless of the target backend. Second, a semantic portability framework verifies that circuit realizations remain equivalent across providers and toolchains, acting as a correctness quality gate. Third, a CI/CD workflow detects transpilation drift before hardware execution: circuits are transpiled against configured target profiles, compared to approved baselines, logged to MLflow, and surfaced as pass/warn/fail feedback in GitHub Actions. We demonstrate the approach with circuits targeting IonQ, IQM, and Rigetti backends. Ongoing work integrates these layers into Kubernetes-native quantum computing (Qubernetes): a drift-triggered operator that gates deployments on portability checks and emits platform-level provenance for every scheduled quantum job — closing the loop from detection to automated remediation.

Local Gate Scheduling as a Continuous Quantum Optimal Control Problem

P013

Jake Muff
VTT Technical Research Centre of Finland

Track: Quantum Computing, Algorithms & Software

Abstract

Compiling quantum circuits for NISQ hardware forces idle windows inside local gate blocks. This is most visible in the CNOT = (I⊗H)·CZ·(I⊗H) decomposition native to superconducting devices, where limited connectivity and gate parallelisation leave qubits idling and decohering. Compilers schedule these windows on a gloval level either as-soon-as-possible (ASAP) or as-late-as-possible (ALAP), often treating the two as equivalent when total circuit duration is unchanged. Prior work [1] applies ALAP globally through discrete, symmetry-based heuristics, but scheduling remains a binary decision operating on the whole circuit. We reframe this as a local, continuous quantum optimal control problem: the fraction $\tau \in [0,1]$ of idle time placed before each entangling gate becomes a continuous variable optimised for fidelity (τ=0 schedules the gate immediately, τ=1 delays it maximally). Simulating a validated tunable-coupler two-qubit digital twin [2] under the Lindblad equation (T_1, T_2, residual ZZ [3]), we find the benefit is driven solely by T_1 amplitude damping — T_2 is timing-symmetric and ZZ is negligible at idle times. Before the CZ the state is separable and robust; afterward the entangled state is fragile to T_1. Placing idle before the CZ (τ_1=1) maximises time spent in the robust state. Extending to a second parameter τ_2 governing post-CZ placement, we find τ_2 has little effect once τ_1=1. We validate on VTT's 50-qubit superconducting processor (VTT Q50). Continuous τ sweeps rise monotonically in both simulation and hardware, confirming τ_1=1 is optimal. For a 5-qubit Tree-GHZ circuit the duration-neutral pass yields +2.76 pp over default ASAP; adding dynamical decoupling (DD) improves ASAP but not beyond τ_1=1, while DD applied on top of τ_1=1 gives +3.08 pp, showing the two are complementary. Across a GHZ scaling study from n=2 to 10 qubits, the advantage grows with qubit count, establishing local ALAP in this case as optimal. To demonstrate scalability on application-relevant workloads, we apply the technique to the preparation of genuine multipartite entanglement via GHZ states utilising the Multiple Quantum Coherence benchmark on up to 30 qubits on VTT Q50, where state-aware idle placement allows larger states to be entangled. Future work targets broader circuit classes and exploring the generalisation of this technique.

[1] K. N. Smith et al., "Error Mitigation in Quantum Computers through Instruction Scheduling," arXiv:2105.01760 (2021).

[2] F. Marxer et al., "Long-Distance Transmon Coupler with CZ-Gate Fidelity above 99.8%," PRX Quantum 4, 010314 (2023).

[3] P. Krantz et al., "A Quantum Engineer's Guide to Superconducting Qubits," Applied Physics Reviews 6, 021318 (2019).

Swinburne Quantum

P014

Tapio Simula
Swinburne University of Technology

Track: Quantum Computing, Algorithms & Software

Abstract

This poster showcases the quantum ecosystem capabilities of, and international collaboration opportunities with Swinburne University of Technology in Melbourne, Australia.

Track: Quantum Foundations, Open Systems & Thermodynamics

Number of Posters: 10

Heat, work and fluctuations in a driven quantum resonator

P015

Riya Baruah
Aalto University

Track: Quantum Foundations, Open Systems & Thermodynamics

Abstract

A central building block of a heat engine is the working fluid, which mediates the conversion of heat into work. In nanoscale heat engines, the working fluid can be a quantum system whose behavior and dynamics are non-classical. A particularly versatile realization is a quantum resonator, which allows for precise control and coupling to thermal reservoirs, making it an ideal platform for exploring quantum thermodynamic processes. Here, we investigate the thermodynamic properties of a driven quantum resonator whose temperature is controlled by modulating its natural frequency. We evaluate the work performed by the external drive and the resulting heat flow between the resonator and its environment, both within linear response and beyond. To further elucidate these processes, we determine the full distribution of photon exchanges between the resonator and its environment, characterized by its first few cumulants. Our results provide quantitative insights into the interplay between heat, work, and fluctuations, and may help in designing future heat engines.

Finnish Quantum Days 2026 Poster P015

Generating autonomous collective coherence in qubits via common heat baths

P016

Kuan-Hsun Chiang
Aalto University

Track: Quantum Foundations, Open Systems & Thermodynamics

Abstract

We experimentally demonstrate destructive interference in steady-state photonic heat transport across a pair of uncoupled superconducting qubits. By applying a temperature bias between common thermal baths that expose the qubits to correlated thermal fluctuations, we observe an interference fringe in the heat current, which indicates the emergence of collective coherence between the two qubits. Our study implies that steady-state collective coherence can be sustained autonomously in a dissipative system, without the need for external coherent drives.

Finnish Quantum Days 2026 Poster P016

Designing non-Hermitian dynamics via rate operator transformations

P017

Jaakko Luomala
University of Turku

Track: Quantum Foundations, Open Systems & Thermodynamics

Abstract

Non-Hermitian dynamics can be realized as post selected evolutions in open quantum systems under continuous measurement. We studied time dependent control of non-Hermitian dynamics in a PT-symmetric Bose-Hubbard model using the rate operator quantum jump formalism.

Heat measurement of quantum interference

P018

Luca Magazzù
Aalto University - School of science

Track: Quantum Foundations, Open Systems & Thermodynamics

Abstract

Coherence is a key property of quantum systems, and it plays a central role in the operation and performance of quantum heat engines and refrigerators. Despite its importance for the fundamental understanding in quantum thermodynamics and its technological implications, coherence effects in AC-driven heat transport have not been observed previously. Here, we measure quantum features in the heat transfer between a qubit and a thermal bath. The system is formed of a driven flux qubit galvanically coupled to a $\lambda/4$ coplanar-waveguide resonator that is in turn coupled to an engineered thermal bath. The latter is a normal-metal mesoscopic resistor, whose temperature can be measured and controlled. We detect interference patterns in the heat current due to driving-induced coherence in the qubit-resonator circuit. Resonance peaks in the heat transferred to the bath are found at driving frequencies which are integer fractions of the resonator frequency. A selection rule on the even/odd parity of the peaks holds at the qubit symmetry point. We present a theoretical model based on Floquet theory that captures the experimental results. The studied system provides a platform for investigating the role of coherence in quantum thermodynamics. Our work opens the possibility to demonstrate a true quantum thermal machine where heat is measured directly.

Christoforus Dimas Satrya et al., arXiv:2510.23092 (2025).

Modeling dissipation and decoherence in qubit systems via the spin-boson model

P019

Joona Marjamäki
University of Jyväskylä

Track: Quantum Foundations, Open Systems & Thermodynamics

Abstract

The usual approach to studying the dynamics of an open quantum system is to use a quantum master equation (QME) with Markovian evolution and weak coupling, leading to the Redfield or Lindblad equations [1]. However, in the presence of strong coupling or a strong driving field, the Markovian time evolution may no longer be valid. We model a qubit coupled to an environment using the spinboson model and examine the effects of strong coupling and driving pulses on the system's dynamics. The pulses represent laser pulses used in the implementation of gate operations between qubits in quantum computers [2]. We investigate how strong systembath coupling influences both the adiabatic preparation of the coupled equilibrium state and the subsequent nonequilibrium dynamics after the twolevel system is driven out of equilibrium. We find that the adiabatic preparation time depends on the specific observable used to assess convergence: when the groundstate energy is the target, the required switching time increases monotonically with coupling strength, whereas for local observables such as Pauli matrix expectation values, the behavior can appear nonmonotonic. Starting from this prepared coupled state, we then track the system's nonequilibrium evolution and relaxation under driving, highlighting how strong coupling controls the postdrive dynamics [3].

[1] H.P. Breuer, and F. Petruccione, The Theory of Open Quantum Systems (Oxford Univer sity Press on Demand, New York, 2002).

[2] E. Pelucchi, G. Fagas, I. Aharonovich, D. Englund, E. Figueroa, Q. Gong, H. Hübel, J. Liu, C.Y. Lu, N. Matsuda, J.W. Pan, F. Schreck, F. Sciarrino, C. Silberhorn, J. Wang, and K. D. Jöns, Nat. Rev. Phys. 4, 194 (2022).

[3] J. Marjamäki, R. van Leeuwen, and R. Tuovinen, manuscript in preparation (2026).

Dirac notation and Born rule as epistemic game when describing quantum optical experiments

P020

Aku Pajula
University of Helsinki

Track: Quantum Foundations, Open Systems & Thermodynamics

Abstract

The introduction of quantum mechanics is seen as difficult due the mathematical formalism required to describe quantum states and measurements. In quantum optics, however, many fundamental phenomena can be represented through interferometric single-photon experiments, providing a natural framework for introducing state vectors. Inspired by the quantum optical approach of Scarani, I present a practical implementation of Dirac's bra-ket notation as a bookkeeping method for tracking single-photon quantum state transformations through optical elements such as beam splitters and their interferometric arrangements. Once the quantum state of the system has been determined, detection probabilities are obtained directly through application of the Born rule. The approach emphasizes state evolution, superposition, entanglement and coherence while avoiding unnecessary mathematical complexities at the introductory level. Dirac notation is treated primarily as a symbolic language for representing physical processes rather than as a heavy computational tool requiring advanced linear algebra. This allows learners to connect schematic representations of quantum optical experiments with the corresponding mathematical quantum state description and probability calculations. The method was implemented in a bachelor level introductory quantum physics course emphasizing quantum optical approach. Student performance was evaluated using weekly assignments and a final examination involving multiple quantum optical scenarios. The analysis focused on the ability to construct quantum state descriptions using the bookkeeping method and to calculate measurement probabilities using the Born rule. Different notation styles adopted by students were also examined to determine whether representational preferences influenced performance. Results indicate that participants were generally able to describe quantum optical experiments successfully using Dirac's bra-ket notation and to obtain correct detection probabilities with Born rule. The most common difficulties were associated with state mapping at successive beam splitters, representation of single-photon Fock states, and interpretation of projections when applying the Born rule. Errors in probability calculations were typically related to inner products and modulus-squared operations. The choice of notation style showed no significant influence on overall performance. These findings suggest that employing Dirac's bra-ket notation as a bookkeeping tool in quantum optics experiments provides an effective route for introducing the mathematical foundations of quantum mechanics. By focusing on physically motivated state evolution and measurement rather than formal mathematical machinery, the approach offers an accessible pathway to learning the central mathematical structures while preserving its essential physical content.

Can Active Information Solve Key Problems in the Bohm Theory?

P021

Paavo Pylkkänen
Philosophy, University of Helsinki

Track: Quantum Foundations, Open Systems & Thermodynamics

Abstract

David Bohm published a "suggested interpretation of quantum theory in terms of hidden variables" in two papers in 1952. He independently rediscovered and completed an approach Louis de Broglie had proposed already in 1927. In Bohm's theory an electron is a particle always accompanied by a field, described by the wave function. The field gives rise to a 'quantum potential' which influences the particle, besides the classical potential. Bohm initially thought of his theory in physical terms: the quantum field is a physical field in some ways like the electromagnetic field, while also having different properties. However, he gradually become critical of his theory, noting that the mathematical form of the quantum potential is arbitrary; that when applied to a many-body system the theory involves the unacceptable assumption of a physical field in a 3N-dimensional configuration space; and that in a measurement situation the theory assumes that unoccupied or empty wave packets are left floating around. In later research Bohm made a radical re-interpretation of the nature of the quantum potential. He suggested that the quantum field should be seen as a field of information rather than as a physical field. This way he claimed to solve the problems of the arbitrary mathematical form of the quantum potential, the problem of the multidimensional nature of the many-body quantum field and the problem of empty wave packets. Bohm's proposal about active information has been by and large ignored in recent philosophy of physics, but my thesis in this poster is that there are good reasons to accept Bohm's own later version of his 1952 interpretation as a serious live option among the interpretations of quantum theory.

P022

Simulating generic single-qubit dynamics via Polarization-Frequency Coupling in a photonic interferometer

Kalle Raikisto
University of Turku

Track: Quantum Foundations, Open Systems & Thermodynamics

Abstract

Controlling and simulating decoherence processes of a quantum system are crucial in the development of quantum technologies, as decoherence degrades their performance. In previous work, reservoir engineering has proven to be key in controlling dephasing processes [1], which we expand into a general decoherence simulator using an interferometric setup. Our simulation platform uses the single-photon Mach-Zehnder interferometer with dephasing introduced in [2]. We show that by engineering the initial polarization-frequency state, we can control the decoherence process as the photon passes through the interferometer. By tailoring the frequency distribution, we receive a large variety of decoherence processes for the polarization qubit. We observe a range of different non-Markovian dynamics, demonstrating the extent of our simulator. Finally, we use our simulator to simulate depolarizing noise for a single qubit, showcasing its theoretical accuracy. Our simulation platform provides the possibility to simulate a variety of Markovian and non-Markovian decoherence processes for qubit systems.

[1] Z.-D. Liu, H. Lyyra, Y.-N. Sun, B.-H. Liu, C.-F. Li, G.-C. Guo, S. Maniscalco, and J. Piilo, Experimental implementation of fully controlled dephasing dynamics and synthetic spectral densities, Nature Communications 9, 3453 (2018).

[2] O. Siltanen, T. Kuusela, and J. Piilo, Interferometric approach to open quantum systems and non-markovian dynamics, Physical Review A 103, 032223 (2021)

P023

Hierarchical Pure States Approach to Non-linear Spectroscopy of Polaritonic Quantum Batteries

Sebastian Toivonen
University of Turku

Track: Quantum Foundations, Open Systems & Thermodynamics

Abstract

Polaritons, hybrid quasi-particles emerging from strong light-matter interaction, offer a promising platform for quantum batteries, where cooperative effects enhance energy storage and transfer. Understanding their dynamics requires accounting for phonon interactions, which can significantly alter energy absorption and emission. In our recent work, we used the hierarchy of pure states (HOPS) method to study phonon-induced effects in the absorption and resonance fluorescence spectra of a quantum dot, capturing non-Markovian and temperature-dependent effects. By extending this approach, we aim to model pump-probe spectroscopy of a polaritonic quantum battery to investigate nonlinear effects and charging dynamics under strong coupling. Future work will focus on developing HOPS-based simulation methods for these processes, with the goal of providing a framework to explore phonon effects in polaritonic quantum batteries and their potential for efficient energy applications.

Open quantum system modeling of an optically trapped nanoparticle

P024

Iita Tuomisto
University of Turku

Track: Quantum Foundations, Open Systems & Thermodynamics

Abstract

We study an open quantum system model for a levitating nanoparticle trapped in an optical cavity by external optical tweezers. The model consists of two interacting quantum harmonic oscillators, one representing the particle's center of mass mode and the other the optical field inside the cavity, which interact with each other and an external environment. By studying the quantum properties of a relatively large particle in a highly controlled environment we aim to bridge the gap between quantum and classical physics. We solve the dynamics of this system in a new way that works even for non-Gaussian states. Starting with the Gorini-Kossakowski-Sudarshan-Lindblad (GKSL) master equation for the density matrix of this system, we unravel it into the corresponding quantum state diffusion (QSD) equation for pure states. Using an ansatz for the pure states, we reduce the complicated QSD equation to a system of six partial differential equations for the state parameters. Using this method we are able to solve many properties of interest for the system, including the expectation values of the system operators as functions of the state parameters and the steady state values for the squeezing parameters of the state.

Track: Quantum Hardware, Devices & Engineering

Number of Posters: 14

Towards optically driven JAWS for quantum circuit control

P025

Simeoni Ahopelto
VTT

Track: Quantum Hardware, Devices & Engineering

Abstract

Josephson effect in a superconducting tunnel junction array is commonly utilized as a primary AC/DC voltage standard due to its ability to generate single flux quantized (SFQ) voltages, and it holds a promise of noise-free control signal generation for quantum circuits. We have demonstrated an optically driven Josephson Arbitrary Waveform Synthesizer (JAWS) consisting of externally shunted Nb–AlOx–Nb Josephson junctions with data transfer up to 60 Gbit/s (4 higher than for typical JAWS) determined using a double-pulse technique. We aim to develop an optical link with clean signal generation for quantum circuit control to mitigate scaling bottlenecks in current state-of-the-art systems. Link to our preprint: https://arxiv.org/abs/2509.05074

Finnish Quantum Days 2026 Poster P025

Emitted power from double quantum dot and hexagonal lattice nanojunctions

P026

Leo Bellassai
University of Jyväskylä

Track: Quantum Hardware, Devices & Engineering

Abstract

We study electroluminescence, the light emission as a consequence of current through nanojunction, through the profile of emitted power. In particular, we focus on the following nanojunction as quantum emitter: a double quantum dot. The model is analyzed for future applications to a hexagonal lattice (a model for a benzene molecule), which can also be extended to periodic structures such as graphene nanoribbons. Non-equilibrium Green's function formalism is used to study the electronic behavior while a classical approach is applied to the radiation field . Using the time-dependent Landauer-Büttiker formalism, which follows from exact analytical solutions to the Kadanoff-Baym equations describing the molecular junction subject to an arbitrary time-dependent bias, we then determine the photon self-energy and the associated emitted power.

Finnish Quantum Days 2026 Poster P026

P027

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

Juan Galván Paz
Aalto University

Track: Quantum Hardware, Devices & Engineering

Abstract

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.

P028

Characterization of superconducting niobium nitride thin films grown by thermal Atomic Layer Deposition

Annika Häkkinen
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Track: Quantum Hardware, Devices & Engineering

Abstract

Metal nitrides are a promising group of superconducting materials for a wide range of quantum technologies and advanced electronic applications. The quality of superconducting thin film is very critical for its properties and achieving high-quality thin films requires precise thickness control and high conformality. These demands are met when growing the films with Atomic Layer Deposition (ALD). ALD enables uniform coating over the whole substrate area and atomic-scale control of film thickness. Among metal nitrides, niobium nitride (NbN) is especially interesting due to its relatively high theoretical critical temperature (17 K) and compatibility with thermal ALD processes. In this work superconducting NbN thin films were grown by thermal ALD at 400–500 °C using NbCl5 and NH3 as precursors. Film thicknesses varied between 16.9 nm and 128 nm and the depositions were done on Si, SiN and sapphire substrates. The effects of film thickness, deposition temperature, substrate choice, and post-deposition annealing (700–1000 °C) on the superconducting and structural properties were investigated. Film characterization was carried out using electrical resistivity and critical temperature measurements, Atomic Force Microscopy (AFM), X-Ray Diffraction (XRD), and Time-of-Flight Elastic Recoil Detection Analysis (ToF-ERDA). Deposited films exhibited promising superconducting properties with critical temperatures up to 13.6 K after annealing at 850 °C and 14.1 K after annealing at 1000 °C. As-deposited films exhibited resistivities down to 524 $\mu\Omega$cm and after annealing resistivities decreased even further to 54 $\mu\Omega$cm.

As-deposited films were slightly nitrogen rich and contained low concentrations of impurities such as O (< 3.2 at.%), Cl (< 3.4 at.%), C (< 0.26 at.%) and H (< 0.45 at.%). After annealing nitrogen content of the films decreased and films became more niobium rich. Superconducting critical temperature was dependent on the film thickness but even the thinnest films (16.9 nm) had a transition temperature of 11.35 K. These results highlight thermal ALD as a viable method for producing high-quality superconducting NbN thin films.

Finnish Quantum Days 2026 Poster P028

P029

Strain-Mediated Coupling Between a Flip-Flop Qubit and a Mechanical Resonator

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Track: Quantum Hardware, Devices & Engineering

Abstract

Hybrid quantum systems combining spin qubits and mechanical resonators offer a promising platform for coherent control and quantum information processing. In this work, we study the coupling between a bismuth donor flip-flop qubit in silicon and a GHz-frequency mechanical resonator, arising from strain-induced modulation of the hyperfine interaction. This mechanism enables coherent spin-mechanical interactions in a solid-state setting. We model the coupled system using a quantum master equation approach to capture both coherent dynamics and dissipative effects. We present results on mechanically induced shifts of the flip-flop qubit transition frequency, as well as coherent exchange dynamics between the flip-flop qubit and the mechanical mode. We further analyze how these effects depend on parameters such as detuning, coupling strength, and resonator occupation. We also extend the model to multiple qubits and demonstrate how a coherently driven mechanical resonator can mediate interactions within a spin ensemble, enabling the exploration of collective dynamics and providing a possible route toward scalable hybrid quantum architectures.

Finnish Quantum Days 2026 Poster P029

P030

Quantum control of subradiant states in transmon pairs

Anna Khylenko
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Track: Quantum Hardware, Devices & Engineering

Abstract

Superconducting qubits are a leading platform in quantum information and computing research. Among them, a superconducting transmon qubit is widely used due to its high controllability and reduced noise sensitivity. Transmons are usually modelled as weakly anharmonic oscillators. Practical implementation of them as qubits requires high isolation from the environment to minimize losses and decoherence, which is challenging to realize. An alternative is to couple several transmons to a common electromagnetic environment and leverage the collective states. A subset of collective states are the so-called dark states, which are decoupled from the environment and protected from decay. Since they form a decoherence-free subspace, they are suitable candidates for quantum information storage and mid-range quantum communication. In this work, we numerically and analytically study a system of two pairs of transmons coupled to a common waveguide. Here, individual pairs are separated by a distance equal to half a wavelength of the transmon frequency. We model the system with an effective

Bose-Hubbard Hamiltonian with experimentally feasible parameters. We analyze the eigenenergy spectrum, the symmetry of the eigenstates, and map the transition pathways. From here, we study the dynamics of the system. The interaction between the waveguide field and transmons gives rise to the so-called local and global eigenstates. Utilizing the local dark states, we show the implementation of arbitrary one-qubit gates with high fidelity. Moreover, by utilizing a selectively driven global dark state, we demonstrate the entangling gates between pairs of transmons. While in our model the sites are separated by a fixed distance, this separation can, in principle, be extended to any integer multiple of the wavelength, enabling entanglement generation over long distances.

Quantum dots as charge sensors for donor spin readout

P031

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Track: Quantum Hardware, Devices & Engineering

Abstract

Silicon is a promising platform for scalable quantum technologies due to its compatibility with existing semiconductor fabrication and its potential for integrating qubits, control electronics, and photonic components on a single chip. Among the various silicon-based qubit implementations, donor spins in silicon offer long coherence times and high control fidelities [1]. However, donor spin readout remains challenging with existing techniques. In this work, we explore the use of silicon quantum dots as charge sensors for donor spin readout. The proposed readout scheme is based on a spin-selective donor-bound exciton transition under an applied magnetic field [2]. The exciton state relaxes via Auger recombination, leading to the ionization of the donor. This ionization can then be detected electrically using nearby quantum dots as charge sensors, enabling donor spin readout. To ensure scalability of the proposed readout approach, we use gate defined silicon quantum dot devices developed by Semiqon Oy. These devices are fabricated on silicon-on-insulator platforms and incorporate on-chip multiplexing architectures, enabling the operation and characterization of multiple quantum dot structures on a single chip [3]. In this presentation, we will discuss the electrical characterization of these devices and evaluate their suitability as charge sensors for donor-based quantum systems.

1. Muhonen, J. et al. Storing quantum information for 30 seconds in a nanoelectronic device. Nature Nanotech 9, 986–991 (2014).

2. Loippo, T et al. Strain effects in phosphorus bound exciton transitions in silicon, Phys. Rev. Materials 7, 016202 (2023).

3. Bohuslavskyi, H. et al. Scalable on-chip multiplexing of silicon single and double quantum dots. Commun Phys 7, 323 (2024).

Superconducting qubits showing T1 > 100us based on etched trilayer junctions

P032

Elsa Mannila
VTT

Track: Quantum Hardware, Devices & Engineering

Abstract

Superconducting qubits are based on Josephson junctions, which are typically realized as aluminum-aluminum oxide-aluminum tunnel junctions fabricated by evaporation and liftoff. However, for scaling up to larger quantum processors requiring high yield and tighter parameter control, fabrication processes based on subtractive patterning methods such as etching carry substantial potential. Here, we present superconducting transmon qubits with Josephson junctions fabricated using a variant of the native oxide passivated trilayer process [1]. The junctions are patterned from an in-situ deposited aluminum-aluminum oxide-niobium trilayer, while a native oxide spacer insulates the trilayer from an additional wiring layer. We find significantly improved T1 times (>100us @ 4 GHz) and quality factors (Q >2.5M) compared to our previous work [1] in transmon qubits with the shunt capacitor patterned from the Nb-based wiring layer. We discuss the loss mechanisms potentially limiting the qubit performance.

[1] Native-oxide-passivated trilayer junctions for superconducting qubits, Phys. Rev. Applied 24 Dec2025. https://doi.org/10.1103/tblt-589d, https://arxiv.org/html/2504.03481v2

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P033

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Track: Quantum Hardware, Devices & Engineering

Abstract

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T-Centers in Silicon : New Candidate for Spin-Photon Interfaces

P034

Nima Nematimansur
University of Jyväskylä

Track: Quantum Hardware, Devices & Engineering

Abstract

Many efforts have been devoted to finding an efficient source of light in silicon with spin-dependent emission to enable the photonic readout of spin-photon interfaces. Their integration in currently highly studied silicon photonic components and the potential scalability of such sources makes them promising candidates for quantum information processing networks. One long-known but recently better-investigated source is T-centers. These color centers in silicon not only exhibit ultra-narrow optical no-phonon transitions in the telecom band, but also electron and nuclear spin lifetimes beyond a millisecond and a second, respectively.

Ultrasensitive bolometers using wafer-scale superconducting transistor technology

P035

Ashish Panigrahi
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Track: Quantum Hardware, Devices & Engineering

Abstract

Measurement of the state of a qubit is a fundamental operation in the realization of NISQ-era quantum computers. Achieving high-fidelity single-shot readout is essential in this regard. Often in the field, quantum-limited parametric amplifiers are used for this reason. In recent years however, ultrasensitive thermal detectors have proven to be viable alternatives due to their low footprint and power consumption, offering scability, sensitivity, and the speed required for high-fidelity qubit readout [1]. The robust process of Josephson field-effect transistor (JoFET) fabrication developed at VTT [2] provides a platform for integrating various building blocks for superconducting quantum circuits. With a bolometer fabricated with this process, the junction is made out of Al – graphene – Al, which presents itself as an ultrasensitive thermometer due to the low heat capacity and weak electron-phonon coupling in the graphene sheet [3]. In addition, these devices can be integrated with superconducting resonators, paving the way for fast, high-fidelity qubit readout. In this work, we present a cryogenic microwave bolometer fabricated with this wafer-scale process, showing promise towards readout of scaled up multi-qubit systems.

[1]: A. Gunyhó et al., Nat Electron 7, 288-298 (2024).

[2]: A.A. Generalov et al., Appl. Phys. Lett. 125, 012602 (2024).

[3]: R. Kokkoniemi et al., Nature 586, 47 (2020).

Improvement of the Simmons model for tunnel junctions

P036

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Track: Quantum Hardware, Devices & Engineering

Abstract

We present an improvement [1] of the so-called Simmons model [2-5], which is a well-known, extremely highly cited (Ref. [3] has more than 3700 citations, for example) and still widely used analytical model to calculate the tunneling current (or conductance) of tunnel junctions, established already in the 1960s. It can be used, for example, to estimate the most critical material parameters of the tunneling barrier, such as its thickness and height in energy, from simple electrical measurements. Such an improvement is relevant for modern science, as tunnel junctions are used more and more in applications in quantum technology, such as building blocks of superconducting qubits, superconducting quantum interference devices (SQUIDs), sensitive radiation detectors, on-chip electronic coolers and thermometers. In the quest to explore more advanced barrier materials and fabrication methods for those applications, the old theoretical models [2-5] reach their limits of applicability, and more accurate models need to be developed, with a wider range of applicability for different barrier types.

References:

[1] Ilmo M. W. Räisänen and Ilari J. Maasilta, "Improvement of the Simmons model for tunnel junctions," J. Appl. Phys. 139, 073902 (2026).

[2] John G. Simmons, "Low-voltage current-voltage relationship of tunnel junctions," J. Appl. Phys. 34, 238–239 (1963).

[3] John G. Simmons, "Generalized formula for the electric tunnel effect between similar electrodes separated by a thin insulating film," J. Appl. Phys. 34,1793–1803 (1963).

[4] John G. Simmons, "Electric tunnel effect between dissimilar electrodes separated by a thin insulating film," J. Appl. Phys. 34, 2581–2590 (1963).

[5] John G. Simmons, "Generalized thermal J -V characteristic for the electric tunnel effect," J. Appl. Phys. 35, 2655–2658 (1964).

A mechanical device engineered for coherent control of spin

P037

Pooja Sudha
University of Jyväskylä

Track: Quantum Hardware, Devices & Engineering

Abstract

Silicon spin qubits combine long coherence times with high-fidelity control and readout, yet their scalability remains limited by lack of efficient coupling mechanisms that can support large-scale integration. Hybrid quantum platforms that harness mechanical or photonic devices offer a promising route to overcome this challenge. Here, I will present our work on a phononic waveguide architecture designed, through COMSOL simulations, to enable coherent coupling with spin qubits in silicon. The proposed device integrates a high-strain phononic region optimized for spin-strain interaction, providing a mechanism for coupling spins to acoustic modes, with an adjacent phononic waveguide that can mediate long-range qubit-qubit coupling across remote spin sites. The waveguide is engineered to resonate with the spin-transition frequency of bismuth donors in silicon, ensuring compatibility with donor-based spin qubits. Our simulations demonstrate that such a hybrid design can provide a scalable

pathway for coherent spin coupling, potentially enabling the construction of larger, interconnected silicon-based quantum architectures. Beyond computation, the framework additionally offers prospects for quantum sensing and transduction.

Finnish Quantum Days 2026 Poster P037

P038

Multiplexed metallic bolometer for 1550nm single photon detection

Shiling Yu
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Track: Quantum Hardware, Devices & Engineering

Abstract

The detection of extremely weak signals is fundamental to advancing quantum computing and quantum communication. For 1550 nm quantum key distribution systems, achieving photon number resolving capability is particularly critical. In this poster, we present a dedicated metallic bolometer which features superconductor normal metal superconductor (SNS) junction as its core sensing element, integrated with specifically designed antenna absorber. This device enables the efficient conversion of incident infrared fiber signals into microwave readout pulses at cryogenic temperatures. Furthermore, it has been extended to support multiplexing, allowing for simultaneous high speed readout across multiple channels. Our preliminary experimental results demonstrate the device's promising sensitivity and response characteristics, highlighting its significant potential for deployment in QKD systems and advanced quantum applications.

Finnish Quantum Days 2026 Poster P038

Track: Quantum Information, Communication & Security

Number of Posters: 8

Nonclassical traits in multi-copy state discrimination

P039

Tim Achenbach
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Track: Quantum Information, Communication & Security

Abstract

Quantum state discrimination is a fundamental information processing task that serves as a building block for numerous applications and provides implications at the foundational level. The aim of state discrimination is to design the optimal strategy to identify the unknown state from an ensemble. In this work, we consider minimum error discrimination of multi-copy states, where instead of preparing a single system we assume that multiple instances of the same state are prepared. Now the discrimination allows for measurements from multiple parties with different measurement strategies varying from global measurement strategy to ones restricted to different forms of local operations and classical communication strategies. By comparing the average success probabilities in quantum and classical cases, we find a qubit strategy that outperforms all the bit strategies. On the other hand, we show that the classical measurement strategy does not give benefit in qubit over bit. However, we find that there are other bit-like operational theories which can outperform the best qubit strategies even with a classical measurement strategy and we are able to identify instances of different theories where different measurement strategies are optimal. In this way, we are able to find instances of nonlocality without entanglement as well as provide general bounds for bit-like operational theories.

Finnish Quantum Days 2026 Poster P039

Quantum Resilient Communication and Cybersecurity

P040

Erik Hieta-aho
VTT
Track: Quantum Information, Communication & Security

Abstract

In recent years the status of quantum computing development has dramatically accelerated, while the preparation for the impact on the security of our digital infrastructure has lagged behind. This poster covers the current options for secure communications and a general over view of the status of transitioning to post quantum cryptography. These topics are covered by our national project Beyond the Limits of PQC in which we are collaborating with industry partners to research and implement the quantum resilient cybersecurity.

Finnish Quantum Days 2026 Poster P040

Semi-device-independent channel identification with communication matrices

P041

Leevi Leppäjärvi
University of Jyväskylä

Track: Quantum Information, Communication & Security

Abstract

We look into the task of differentiating between any two quantum channels and reconstructing them from the obtained measurement statistics with possibly limited information about the experimental set-up. We employ the communication matrix formalism where the measurement statistics of a prepare-and-measure scenario is represented as a stochastic communication matrix. In order to differentiate between any two quantum channels, the informational completeness of the set-up is both necessary and sufficient. On the other hand, if we want to uniquely characterize any quantum channel, in addition we also need to have a complete description of the set-up. We show that in many important cases we can deduce this information directly from the communication matrix of the set-up before applying the channel. Given that we trust the dimension of the system, we show that we can deduce the information completeness of the set-up directly from the rank of the communication matrix. Furthermore, we show that another quantity of the communication matrix, called the information storability, can be used to self-test the set-up (up to unitary or antiunitary freedom) for an important class of qubit states and measurements. This provides us a semi-device-independent way to identify quantum channels from the prepare-and-measure statistics. Lastly, we consider scenarios where we might have some additional information about the channels or additional resources at our disposal which could help us relax some of the assumptions of the proposed scenario.

Finnish Quantum Days 2026 Poster P041

Noise or Eavesdropper? Effects on Quantum Instruments

P042

Andrés Damián Muñoz Moller
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Track: Quantum Information, Communication & Security

Abstract

Performing a quantum measurement yields two different results: a classical outcome drawn from a probability distribution, according to Born's rule, and a quantum outcome corresponding to the post-measurement state. Quantum devices that provide both outcomes can be described through quantum instruments. In a realistic scenario, one can expect that the observer's obtained classical and quantum outcomes are non-ideal: this can be due to experimental limitations, but could also be explained by adversarial interference, that is, a second party that disturbs the device through a concealed measurement to obtain information. The second scenario can be interpreted through quantum compatibility, as it implies that both the observer's instrument and the adversary's measurement can be performed simultaneously. In this work, we show how the noise of the observer's device relates to the amount of information that the adversary can obtain. We study scenarios in which the adversary aims to acquire information on the same basis as the observer's measurement, or on a mutually unbiased basis with respect to the observer's basis. In both cases, we derive necessary and sufficient conditions for the compatibility of a single qubit non-ideal quantum instrument and a noisy meter, from which we obtain the maximum amount of information that the adversary can extract in terms of the noise parameters of the observer's instrument. Finally, we provide the device implementation from the adversary's point of view for the same basis scenario.

P043

Stabilizer-based quantum random access codes

Matti Raasakka
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Track: Quantum Information, Communication & Security

Abstract

Quantum random access codes (QRACs) provide a provable quantum advantage in a simple communication task. They can also be utilized for device semi-independent certification of quantum computers. In this work we construct a family of generalized QRACs based on multi-qubit stabilizer states and their linear combinations. The construction provides a systematic way to formulate high dimensional QRACs and highlights the role of non-stabilizerness in achieving the quantum advantage.

P044

Classification of security challenges and mitigation approaches in the quantum software engineering

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Track: Quantum Information, Communication & Security

Abstract

Quantum Software Engineering (QSE) is an emerging discipline devoted to specifying, designing, implementing, and deploying software for quantum computers. As quantum mechanics and hybrid architecture are evolving at a rapid pace, security challenges are also emerging. This paper investigates the key QSE security concerns, classifying them into four major families: crosstalk, side-channel, fault injection, and pulse-level attacks. For each of these threats, we explore their place of origin, consequences, and available specimens. In response, we map mitigation approaches such as dynamical decoupling, randomized compiling, transpilation masking, secure lifecycle models, frameworks, and associated tools.

Hybrid quantum networks - electro-optic microwave to optical transduction

P045

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Track: Quantum Information, Communication & Security

Abstract

Hybrid quantum networks are one way to address the scalability issue of quantum computers. If a coherent link between microwave qubits (e.g. superconducting or spin based quantum computers) and optical qubits (e.g. ion/atom based quantum computers) would exist, that would allow such quantum computers to be entangled, scalability would not be an issue. We present a new design based on our original electro-optic transduction work [Rueda et al. Optica 2016, Hease et al. PRX 2020] that promises to achieve conversion efficiency to make deterministic entanglement between cryogenic systems over a room-temperature link feasible.

Finnish Quantum Days 2026 Poster P045

Experimental high-dimensional multi-qubit Bell non-locality on a superconducting quantum processor

P046

Yousef Mafi
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Track: Quantum Information, Communication & Security

Abstract

Combining recent advances in superconducting quantum hardware, we explore quantum correlations in a previously inaccessible regime by observing simultaneously high-dimensional and many-body Bell non-locality. We report a high-confidence Bell violation in the correlations between two d=64-dimensional systems encoded in twelve qubits. For system sizes up to d=32, the strength of the observed nonlocal correlations exceeds the quantum upper bound for d=2 systems, providing direct evidence of high-dimensional nonlocality. Furthermore, we demonstrate that the observed violation is genuinely collective: all qubits contribute to the nonlocal correlations, while most pairwise correlations across the bipartition remain Bell-local. Our work illustrates how present-day quantum processors enable the exploration of fundamental predictions of quantum mechanics in previously inaccessible regimes and, in turn, how fundamental quantum effects can be used to benchmark their performance.

Finnish Quantum Days 2026 Poster P046

Track: Quantum Materials, Superconductivity & Many-Body Physics

Number of Posters: 18

P047

Playing 'Hide & Seek' at Atomic-scale

Zuned Ahmed
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Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

The layered transition-metal telluride compound $TaCo_2Te_2$ has attracted growing attention because of its fermionic band degeneracy, air-stability, and low-dimensional crystal structure [1,2]. In this work, we investigate the structural, electronic, and magnetic properties of $TaCo_2Te_2$ using a combination of experimental characterization techniques and density-functional theory. $TaCo_2Te_2$ exhibits a distorted crystal structure in which the top Te atoms occupy three nonequivalent positions, giving rise to distinct structural morphologies depending on the scanning probe technique employed. In particular, constant-current scanning tunneling microscopy (STM) images reveal a square-like surface electronic structure, whereas constant frequency-shift atomic force microscopy (AFM) images display a pseudohexagonal arrangement. Furthermore, the electronic properties of $TaCo_2Te_2$ is examined using scanning tunneling spectroscopy (STS), and the obtained results are consistent with complementary angle-resolved photoemission spectroscopy (ARPES) measurements.

[1] H. Rong et al., npj Quantum Mater. 8, 29 (2023).

[2] R. Singha et al, Adv. Funct. Mater. 32, 2108920(2022).

P048

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Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

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Josephson anomalous vortices and rotary invariants

P049

Dan Crawford
University of Jyväskylä

Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

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.

Transport and spectral properties of disordered Rashba superconducting diodes

P050

Maryam Darvishi
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Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

Theoretical descriptions of superconducting transport are often restricted to either the ballistic or diffusive limit, while many experimentally relevant samples lie in the moderately disordered regime between these two limits. Here, we use the nonlinear Eilenberger formalism to study two-dimensional Rashba superconductors with an in-plane Zeeman field across the full range of impurity scattering strengths. We investigate how disorder modifies nonreciprocal superconducting phenomena, including the superconducting diode effect and nonlinear kinetic inductance, together with the current-induced Edelstein effect and the quasiparticle density of states. Our theory is relevant to a new generation of superconducting platforms, including semiconductor heterostructures with strong spin-orbit coupling and van der Waals materials.

P051

Critical Current of Flat-Band Superconductors

Aaron Dunbrack
University of Jyväskylä

Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

One characteristic feature of flat-band superconductors is their short (lattice-scale) coherence lengths. This enables superconductivity to be stable at relatively high phase gradients. We examine the consequences of this for critical current - including quantum-geometric contributions thereto - and for superfluid weight at finite current.

P052

Realizing orbital ordering in a monolayer van der Waals multiferroic

Somesh Ganguli
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Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

Orbital degrees of freedom are predicted to host unconventional symmetry-broken phases, yet direct experimental realizations of orbital-ordered states in two-dimensional systems remain scarce. Two-dimensional magnets, since its inception, show a multitude of correlated phenomena, including ferromagnetism in CrX3 compounds, multiferroicity in the NiX2 family, and quantum spin liquid behavior in RuCl3. Among these, monolayer VCl_3 is uniquely suited for realizing orbital-driven ordering [1]. Its partially quenched orbital moment, arising from reduced spin–orbit coupling and residual d-orbital degeneracy, provides a correlated platform where orbital physics can dominate symmetry breaking [2]. In our work, we demonstrate the first observation of antiferro-orbital ordering in monolayer VCl3 grown on highly oriented pyrolytic graphite. Using spectroscopic imaging scanning tunneling microscopy, we identify an interaction-driven ground state characterized by a reduction of the threefold (C3) symmetry to twofold (C2) symmetry in the local density of states (LDOS), concomitant with a ferroelectric lattice distortion, establishing a multiferroic phase rooted in orbital ordering. Inelastic tunneling spectroscopy reveals a collective excitation that exists exclusively within the orbital-ordered phase, indicating coupled dynamics of orbital and magnetic degrees of freedom. Remarkably, application of an external magnetic field quenches the ferroelectric polarization, restores the C3 symmetry in the LDOS, and suppresses the collective mode, demonstrating reversible magnetic control of intertwined orbital, lattice, and spin sectors. Our findings reveal a field-tunable multiferroic phase in a layered van der Waals magnet, identify orbital order as the driving symmetry-breaking mechanism, and pave the way for multiferroicity-enabled and orbitally engineered quantum electronics.

References:

[1] L. Camerano, A. O. Fumega, G. Profeta, and J. L. Lado, Multicomponent magneto-orbital order and magneto-orbitons in monolayer VCl3, Nano Letters 25, 4825 (2025).

[2] L. Camerano and G. Profeta, Symmetry breaking in vanadium trihalides, 2D Materials 11, 025027 (2024).

Dipolar Droplets and Supersolids

P053

Ratheejit Ghosh
University of Jyväskylä

Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

Dipolar quantum gases are at the forefront of exploring complex many-body physics due to the anisotropic and long-range nature of dipole-dipole interactions. Ground-breaking discoveries of quantum droplets and supersolids have sparked interest in their existence, leading to numerous new studies. In this context, we investigated the physics of doubly dipolar Bose-Einstein condensates, characterized by competing dipolar interactions arising from both electric and magnetic dipole moments within each boson. Remarkably, our studies revealed the formation of pancake droplets, contrary to the usual cigar droplets, which subsequently led to the discovery of a pancake supersolid. Pancake droplets exhibit intriguing finite temperature properties, which we explored using quantum Monte Carlo techniques. Finally, we demonstrate the surprising emergence of supersolids in a dipolar condensate under rotation, stabilized by quantized vortex lines.

Finnish Quantum Days 2026 Poster P053

Coherent subgap transport in spin-split Josephson junctions

P054

Alberto Hijano Mendizabal
University of Jyväskylä

Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

We report the first experimental observation of subgap transport in ferromagnetic insulator–superconductor–insulator–superconductor junctions realized in EuS/Al/AlOx/Al vertical stacks. Differential conductance measurements reveal multiple Andreev reflection peaks, with odd-order peaks split by the spin-splitting induced in the superconductor adjacent to EuS, while even-order peaks remain unaffected. Combining experiments with quasiclassical transport modeling, we extract the spin-splitting and an approximate distribution of transmission channels. Our work establishes EuS/Al junctions as a versatile platform to study subgap transport, Josephson coupling, and spin-polarized superconducting phenomena.

Finnish Quantum Days 2026 Poster P054

Fluxoid solitons in bottlenecks

P055

Tim Kokkeler
University of Jyväskylä

Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

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 depending on the applied magnetic field. The bottleneck then becomes a topological boundary and is host to topologically protected solutions for the order parameter, dubbed fluxoid solitons, that are free to move around bottlenecks with cylindrical symmetry. Fluxoid solitons are a new type of vortex with nonquantized flux, loosely related to Pearl vortices in thin superconducting films, and fluxons 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 trapped fluxoid solitons adopt elaborate arrangements dictated by their mutual repulsion.

Unconventional Josephson Effect in Superconductor-Quantum Spin Liquid Junctions

P056

Curie Lee
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Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

Superconductor-magnet hybrid heterostructures represent a cornerstone of quantum technologies, providing platforms for superconducting diodes and topological qubits. The interplay between superconductivity and classical symmetry broken states has been widely studies, however, the hybrid structures combining superconductivity and quantum magnetism remain a substantially unexplored territory. Here we demonstrate the emergence of unconventional Josephson effect in superconductor/quantum spin liquid tunnel junctions. The system consists of two conventional s-wave superconductors coupled through narrow quantum spin liquid insulator. In this geometry, interface-induced solitonic in-gap modes emerge at each superconductor-spin-liquid boundary, mediating the supercurrent contribution. We show the emergence of a 4π-periodic Josephson effect in the absence of symmetry breaking, and enabled by the quantum magnetic ground state of the tunnel barrier. This anomalous phase response does not rely on topological superconductivity or explicit time-reversal symmetry breaking. Our results establish quantum spin liquids as active mediators of unconventional Josephson physics and demonstrate that many-body modes can induce fractional Josephson effects in otherwise topologically trivial superconducting heterostructures. Our work puts forward a new strategy to engineer anomalous Josephson responses using many-body quantum spin systems in low-dimensional systems, and demonstrating the potential of quantum spin liquids as building blocks for future superconducting spintronic devices.

From polaron formation to superconductivity in flat-band systems

P057

Natale Matranga
University of Jyväskylä

Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

The interaction between electrons and lattice vibrations affects many properties of materials and, in particular, mediates superconductivity. In conventional systems, where electronic energies are much larger than phonon energies, the separation of energy scales justifies the adiabatic approximation as established by Migdal's theorem, providing the foundation for Eliashberg's theory of superconductivity. Conversely, flat-band systems feature nearly dispersionless bands, meaning the electronic energy scale falls well below the phonon frequency. This drives the system into the antiadiabatic regime, where Migdal's theorem breaks down. Within this antiadiabatic framework, the effective electron–phonon coupling is strongly enhanced, stabilizing a polaronic phase where electrons become dressed by a cloud of virtual phonons. As a consequence, the ground state of such systems deviates from a standard Fermi liquid, limiting the applicability of conventional superconductivity theories. Motivated by these considerations, we investigate how polaron formation influences electron pairing and the conditions under which it could lead to superconductivity in flat-band materials.

AETHER: Adaptive Multiconfigurational Simulations of Fermionic Quantum Matter with Long-Range and Cavity-Mediated Interactions

P058

Paolo Molignini
University of Jyväskylä

Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

Ultracold atomic systems have emerged as one of the most versatile platforms for quantum simulation, enabling the controlled realization of strongly correlated many-body phenomena with tunable interactions, dimensionality, and geometry. However, accurately describing these systems – particularly fermionic gases with long-range or cavity-mediated interactions – remains a major theoretical challenge due to the interplay of strong correlations, continuum degrees of freedom, and real-time dynamics. In this work, we introduce AETHER (Adaptive Expansion of Time evolving Hilbert space with Error Reconciliation), a next-generation multiconfigurational framework that dynamically adapts its variational space using a local in time error estimator. This enables accurate and scalable simulations of fermionic quantum simulators in regimes beyond the reach of mean-field, tensor-network, or quantum Monte Carlo approaches. We demonstrate the capabilities of AETHER across a range of experimentally relevant scenarios, including (i) quench dynamics of spinful fermions and emergent pairing mechanisms, (ii) long-range interacting systems in two dimensions exhibiting fluid-to-crystalline transitions, and (iii) cavity-mediated fermionic systems displaying superradiant behavior. Our results establish AETHER as a powerful tool for bridging theory and experiment in quantum simulation and for exploring emergent many-body phenomena in intermediate regimes of quantum matter.

Efficient scanning-probe spectroscopy using Wannier-based nonequilibrium Green's functions

P059

Oscar Moreno Segura
University of Jyväskylä

Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

Scanning tunneling microscopy and spectroscopy (STM/STS) provide powerful tools for probing electronic properties at the atomic scale. On the theoretical side, density functional theory (DFT) and Wannier-based methods allow realistic first-principles descriptions of complex nanosystems. However, modeling nonequilibrium transport remains a significant challenge, especially in superconducting hybrid systems where particle-hole correlations must be treated explicitly. Accurate and efficient theoretical simulations are therefore essential for interpreting experimental measurements and understanding the underlying transport mechanisms. Here, we present a workflow that combines Wannierized first-principles electronic structure calculations with the nonequilibrium Green's function formalism to enable efficient simulations of STM experiments [1]. This approach builds upon standard DFT packages to construct compact transport Hamiltonians that retain the electronic properties of realistic materials. Superconductivity is incorporated through an effective pairing potential within the Nambu-spinor formalism, while the coupling to the STM tip and substrate electrodes is treated within the wide-band limit approximation. Within this framework, transport quantities such as current-voltage characteristics are evaluated in closed analytical form. This substantially reduces the computational cost of spectroscopic calculations. The method provides a unified and computationally efficient approach for modeling superconducting hybrid nanostructures featuring spin-orbit coupling, magnetic textures, and spin polarization. Representative applications demonstrate its robustness and versatility for both simple model systems and realistic ab initio molecular structures relevant to modern STM experiments.

[1] O. Moreno Segura et al., manuscript in preparation (2026).

Entanglement Dynamics in a Second-order Topological Insulator

P060

Mahla Moridi Farimani
Tampere University

Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

Identifying Second-Order Topological Insulators (SOTIs) in experimental settings is a significant challenge because their defining signatures, localized corner states, are difficult to distinguish directly. In this work, we propose a dynamical approach to uncover the topological nature of SOTIs by investigating entanglement dynamics following a quantum quench. Using a square lattice model with open boundary conditions, we initialize the system in a ground state and perform a quantum quench by a sudden change in the mass parameter. We analyze the results of the non-equilibrium dynamics using the rate function (entanglement echo), the entanglement spectrum, and time-dependent particle number variance. Our results demonstrate that while trivial-to-trivial quenches yield a gapped spectrum as well as smooth behavior in the rate function and particle number variance, topological-to-trivial and trivial-to-topological quenches not only exhibit distinct gap closings in the entanglement spectrum but also signal the presence of corner modes in the rate function and particle number variance. In particular, we propose the latter as a potentially experimentally viable tool for detection of these effects. To further focus on experimental applicability, we explore the impact of disorder on these dynamical signatures, examining the effects of pre- and post-quench disorder on the entanglement measures. This research highlights

entanglement dynamics as a robust tool for identifying higher-order topological insulators.

Finnish Quantum Days 2026 Poster P060

Theory of supercurrent induced domain wall movement

P061

Risto Ojajärvi
University of Jyväskylä

Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

We present a theory for moving domain walls using supercurrents. The movement of domain walls plays an important role in racetrack memory, in which information is stored into domain walls. If such movement can be achieved with supercurrents, the energy consumption of racetrack memory could be greatly reduced. We show that supercurrent induced domain wall movement can be achieved by using spin-orbit coupling to induce triplets that have zero spin projection along the easy axis of the ferromagnet. Contrary to conventional wisdom, we find that equal-spin triplets merely increase the anisotropy energy of the spins in the middle of the domain wall.

Finnish Quantum Days 2026 Poster P061

Interplay of Skyrmions, Spin–Orbit Coupling, and Superconductivity

P062

Ewa Swierkosz
University of Jyväskylä

Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

Magnetic/superconducting heterostructures provide a platform for studying transport phenomena where topology, spin–orbit coupling and non-collinear magnetic order are relevant. We consider an s-wave superconductor proximitized by a skyrmionic magnetic texture, where the real-space topology of the magnetization acts as a source of spin-dependent superconducting response. The main goal is to understand how skyrmion topology influences charge and spin currents in the diffusive superconducting state, and how spin–orbit coupling influences this connection. We focus on the quasiclassical Usadel description, where superconducting correlations evolve in the presence of spatially varying exchange fields and experience spin mixing. In this framework, the skyrmion texture generates spin-polarized superconducting components whose structure is tied to the local winding of the magnetization. These provide a microscopic route by which topology can affect measurable transport properties, including equilibrium currents, magnetoelectric responses and vortex–skyrmion coupling. We aim to identify which current contributions originate from the skyrmion texture itself, which require spin–orbit coupling, and how their symmetry reflects the underlying topological charge. By connecting diffusive equations to effective phenomenological descriptions the project offers a route to relate superconducting transport to experimentally observable magnetic textures.

Finnish Quantum Days 2026 Poster P062

p-wave magnetism and superconductivity

P063

Devesh Vaish
University of Jyväskylä
Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

We investigate the properties of normal-state p-wave magnets and their interplay with superconductivity. We first analyze the intrinsic symmetries of the normal-state p-wave magnet, which allows us to identify which gaps are symmetry protected and which are not, as well as to understand the relations between different eigenstates of the system. We then introduce superconductivity through an on-site Hubbard interaction. Recent studies have suggested that p-wave magnets can be viewed as non-relativistic analogs of spin–orbit-coupled (SOC) systems due to their odd k-dependent spin splitting. However, unlike SOC systems, which preserve time-reversal symmetry, p-wave magnets break this symmetry. Instead, they possess a distinct symmetry that additionally involves translation. We therefore examine the similarities and differences between these two classes of systems in greater detail. As a consequence of these differences, we expect p-wave magnets to suppress superconductivity, in contrast to the behavior typically observed in SOC systems.

Adaptive Multiconfigurational Simulations of Fermionic Quantum Matter with Long-Range and Cavity-Mediated Interactions via the AETHER framework

P064

Taylor Baird
Stockholm University
Track: Quantum Materials, Superconductivity & Many-Body Physics

Abstract

Many of the most interesting regimes of ultracold quantum matter lie between two familiar limits: they are too strongly correlated for mean-field descriptions, yet too large, high-dimensional, or dynamically complex for exact many-body methods. This intermediate regime is especially important for modern fermionic quantum simulators, where long-range interactions, optical cavities, spin degrees of freedom, and continuum motion can all play a central role. Developing tractable methods that can follow correlation growth in such systems is therefore essential for interpreting current experiments and guiding future ones. Here we present AETHER (Adaptive Expansion of Time-Evolving Hilbert space with Error Reconciliation), a multiconfigurational framework for continuum fermionic systems with non-trivial interactions and time-dependent dynamics. Rather than fixing the variational space in advance, AETHER monitors the local error of the evolving many-body state and uses it to adapt the Hilbert space during the simulation. This allows the method to construct a compact representation of the relevant correlations as they emerge, providing a controlled route beyond static-basis multiconfigurational calculations. We demonstrate the application of AETHER within a paradigmatic setting, namely two-dimensional long-range interacting fermions, where increasing interaction strength drives a crossover from delocalized fluid-like states to spatially ordered crystalline structures. These features position AETHER as a flexible framework for correlated fermionic matter in experimentally relevant continuum settings, offering a practical route for connecting microscopic theory, numerical simulation, and emerging quantum-simulation experiments.

Track: Quantum Optics, Photonics, Sensing & Metrology

Number of Posters: 13

European QUantum Infrastructure Project for Gravimetry (EQUIP-G) and the role of the FGI

P065

Mirjam Bilker-Koivula
National Land Survey of Finland, FGI

Track: Quantum Optics, Photonics, Sensing & Metrology

Abstract

As quantum technology advances, quantum gravimeters provide increasingly precise measurements of mass variations at different altitudes, enhancing our understanding of Earth's internal dynamics and supporting strategic decisions in energy and environmental management. The EU-funded EQUIP-G project brings together 20 partners from 11 European countries to test, develop, and implement a European quantum gravimeter network. In the 4-year project, a set of quantum gravimeters, dual quantum gravi-gradiometers and an onboard quantum gravimeter will be deployed in a variety of field settings around Europe to demonstrate the potential of the quantum gravity network to contribute to EU priorities, such as Green Deal, energy management and risk mitigation. The instruments will be comprehensively tested and compared. Data will be handled following the FAIR principles. In 2026 the Finnish Geospatial Research Institute (FGI) procured the AQG-B17 quantum gravimeter as part of EQUIP-G. Before deployment in the project use cases, the instrument was tested at the gravity labs of LNE in Trappes, France, FGI in Metsähovi, Finland. As a national standards laboratory the FGI is responsible for the absolute quantum gravimeter comparisons in the project. The purpose of the comparisons is to ensure the traceability of the gravity measurements to SI-units and verify, e.g., the interoperability of the gravimeters. The first comparison of six absolute quantum gravimeters and three traditional absolute gravimeters, including FG5X-221 of the FGI, was organized in April 2026. Processing of the comparison results is ongoing. Additionally, the FGI leads the geothermal use case where the AQG-B17 of FGI will be deployed on the Theistareykir geothermal field in Iceland, first briefly in autumn 2026 and later for continuous measurements of three months during the summers of 2027 and 2028. The geothermal area has been monitored already for years by superconducting gravimeters (SGs) which need regular calibrations to control their drift and scale. The use case will demonstrate the suitability and advantages of using absolute quantum gravimeters for geothermal monitoring and provide the necessary references for SGs in the field.

Towards Dark State Retention in Weakly Anharmonic Photon-Emitter Pairs

P066

Christopher Campbell
University of Oulu

Track: Quantum Optics, Photonics, Sensing & Metrology

Abstract

Dark states are excited quantum states that decouple from their environment in such a way that they do not emit or absorb external photons. In the Bose-Hubbard model, these states are formed when the dissipative interactions between two sites that arise from an open quantum systems dynamics are incorporated in the Hamiltonian. For higher excitations past the qubit model (where the number of excitations exceed one), these states are sensitive to on-site interactions causing these dark states to become dissipative. The origin of this dissipation and the dynamics can be difficult since introduction of this non-linear interaction produces non-Hermitian artifacts such and biorthogonal relationships and wavefunction coalescence. This leads to numerical instabilities in theoretical simulations and loss of information of the initial state when the system is prepared. In a recent study, we have demonstrated how utilizing on-site interactions and anharmonicity as a weak perturbation can circumnavigate the problems associated with non-Hermitian artifacts and found that the origin of this dissipation is primarily due to an induced correlation between the dark states and neighboring dissipative state. This effectively opens a transition path between the states permitting the dark state to relax into a metastable state through a dissipative channel. To extend the findings of this work, we investigate state-preserving protocols with the objective to suppress the correlations induced between the dark and dissipative states. To do this we propose utilizing methods inspired by quantum control protocols such as counter-diabatic driving in order suppress the correlations with the goal to find efficient state preparation and dark state retention methods.

Finnish Quantum Days 2026 Poster P066

Microwave Quantum Optics with Cryogenic Thermal Detectors

P067

Qi-Ming Chen
Aalto University

Track: Quantum Optics, Photonics, Sensing & Metrology

Abstract

Propagating photons serve as essential links for distributing quantum information across distant nodes. While optical quantum networks are well-established, detecting microwave photons at the quantum limit remains a formidable challenge. In this talk, I will first show how we adapt the bolometry technique from cosmological experiments to the field of superconducting quantum circuits and achieve record-breaking sensitivity. I will then demonstrate how this extreme sensitivity enables pioneering applications, including single-shot qubit readout, second-order photon correlation measurements, and the direct observation of the Heisenberg uncertainty relation. Finally, I will discuss how this technology is poised to facilitate fundamental tests of quantum mechanics and serve as an integrated probe for a modular and reconfigurable analogue quantum simulator.

Finnish Quantum Days 2026 Poster P067

Magneto-optical imaging of superconducting vortices at sub-Kelvin temperature

P068

Megan Dransfield
Aalto University

Track: Quantum Optics, Photonics, Sensing & Metrology

Abstract

The understanding of the formation and dynamics of superconducting vortices is essential to predict and harness energy dissipation in quantum devices. By using a magneto-optical indicator film with near-record sensitivity, we realize wide-field real-time images of the stray field from vortices on the surface of superconductors at sub-Kelvin temperatures where quantum devices operate. By visualizing the vortex dynamics in a non-invasive way, we can work on improving the performance and coherence of quantum circuits.

Finnish Quantum Days 2026 Poster P068

Polarization structures of quantized light in relativistic frames

P069

Behnaz Fazlpour
University of Eastern Finland

Track: Quantum Optics, Photonics, Sensing & Metrology

Abstract

We study polarization of quantized light in Lorentz transformations. We derive general expressions for the Lorentz-transformed quantum polarization fluctuations and their uncertainty relations of a plane wave. It is demonstrated how the transformed quantum polarization fluctuations depend on the velocity when the field in the rest frame is in a coherent state and a number state. We also show that the degree of 3D polarization of blackbody radiation, and thus of 3D fields in general, is not preserved under Lorentz transformations. This property is in striking contrast to the Lorentz invariance of the degree of 2D polarization of transverse fields. A moving observer will experience the initially fully 3D unpolarized blackbody radiation as a partially polarized 3D field, and ultimately as an unpolarized 2D planar field when approaching the speed of light.

Finnish Quantum Days 2026 Poster P069

Quantum uncertainty in vector-light interference

P070

Martti Hanhisalo
University of Eastern Finland

Track: Quantum Optics, Photonics, Sensing & Metrology

Abstract

The uncertainty principle is a primary concept in quantum physics and a major manifestation of complementarity. It states that quantum objects may have complementary observables whose values cannot be simultaneously known with ultimate precision. Light is known to exhibit such quantum uncertainty via its several fundamental properties including amplitude, phase, and polarization. Recently, quantum uncertainty of optical coherence was discovered and the concept of coherence squeezing in scalar-light interference was studied. Here, we examine quantum uncertainty in double-slit vector-light interference. We construct 16 Hermitian operators that fully characterize the polarization and coherence properties of light at the slits. We study the commutators of these polarization and coherence operators and discover underlying SU(2) symmetries between them. Subsequently, we derive uncertainty relations that set fundamental boundaries on the characterization precision of polarization and vector-light coherence. We also examine how these quantum uncertainties in the slit plane affect the intensity and polarization fluctuations in the interference pattern. Our work provides a theoretical foundation for understanding and exploring quantum fluctuations of genuine vectorial light in optical interference.

Finnish Quantum Days 2026 Poster P070

Optical Properties of Metal-Ion-Mediated Au25 Nanocluster-Based Assemblies

P071

Hanna Jääskö
University of Jyväskylä

Track: Quantum Optics, Photonics, Sensing & Metrology

Abstract

Building cluster-assemblies from superatomic building blocks, where each cluster behaves as an elemental atom, has attracted interest in the past decades due to their enhanced optical properties. Herein, we study the optical properties of recently discovered gold nanocluster assemblies mediated by Mg(II), Co(II), Ni(II) and Cu(II) metal ions [1] using time-dependent density functional theory (TDDFT). Depending on the coordinating metal ion, the assemblies exhibited different absorption spectra with a redshift of up to 51 nm. Surprisingly, our calculations revealed that the assemblies have chiroptical response, despite being assembled from achiral building blocks [2]. The chirality emerges from the coordination complex formed between the coordinating metal ions and the carboxylic acid groups of the ligands, and is transferred to the achiral nanoclusters. These theoretical findings may influence experiments to create enantioselective nanocluster assemblies.

References:

[1] Kim, S., Jääskö, H., Park, K. C., Malola, S., Häkkinen, H., & Park, S. S. Tuning the Electrical Properties through Metal-Ion-Mediated Assembly in Au25 Nanocluster- Based Frameworks. Journal of the American Chemical Society Vol. 147, p. 30803 (2025).

[2] Jääskö, H., Malola, S., and Häkkinen, H., Optical Properties of Metal-Ion-Mediated Au25 Nanocluster-Based Assemblies. Physical Chemistry Chemical physics, 2026.

Organic microcavity polariton emission with non-Markovian quantum state diffusion

P072

Timo Leppälä
University of Turku

Track: Quantum Optics, Photonics, Sensing & Metrology

Abstract

The collective light-matter coupling between the electronic states of a large number of organic molecules and the electromagnetic field in a cavity results in hybrid light-matter states called polaritons. The electronic states of the molecules and the cavity modes form an open quantum system that interacts with the molecular vibrations and loses photons through the imperfect cavity mirrors. We model the environment interactions with non-Markovian quantum state diffusion and calculate the evolution of the system with hierarchy of pure states. We fit the emission spectrum of the bare molecules calculated from this model to experimental data to get realistic parameter values for the molecules. Then we add the cavity and calculate the emission spectrum of the whole polariton system. Multiple cavity modes are included which allows us to calculate the emission at different angles.

Superradiance in Transmon Arrays with Strong Nonlinearity

P073

Brij Mohan
University of Oulu

Track: Quantum Optics, Photonics, Sensing & Metrology

Abstract

Superradiance in transmon arrays provides a controllable platform for exploring collective light-matter interactions beyond the ideal two-level approximation. In this work, we analytically study a chain of strongly anharmonic transmons coupled to a common radiative channel, allowing for site-dependent frequencies, site-dependent anharmonicities, and nearest-neighbor coherent hopping. Starting from a bosonic multilevel description based on the Bose-Hubbard model, we derive an effective Lindblad master equation within the qubit subspace in the strong-anharmonicity regime, where the anharmonicity is much larger than both the hopping strength and the radiative decay rate. Although population leakage to higher transmon levels is strongly suppressed in this regime, virtual leakage processes remain active and modify the reduced qubit-subspace dynamics. These processes generate corrections to the effective Hamiltonian and collective jump operator, leading to modified collective decay rates and coherent exchange interactions. We obtain general analytical expressions for an N-transmon chain and present explicit results for small arrays with N=3, 4. The resulting effective master equation is in Lindblad form and hence generates completely positive and trace-preserving dynamics. We also found that, the exact and effective dynamics show good agreement for realistic parameters. Our framework is also relevant to other strongly nonlinear bosonic platforms, including polaritonic systems and moiré materials, and provides analytical guidance for engineering superradiant collective phenomena in waveguide QED.

Generation of Wigner-negative states from a coherently driven qubit in waveguide

P074

Gaetano Salvemini
University of Jyväskylä

Track: Quantum Optics, Photonics, Sensing & Metrology

Abstract

This work is a detailed analysis of a protocol to generate states of the electromagnetic field with negative Wigner functions, i.e. non-classical states, starting from classical fields and harnessing the interactions with quantum emitters. The analysed protocol uses a two-level atom coupled to a chiral waveguide and driven at resonance by a coherent field. The key idea is to select, among the infinite modes of the propagating field scattered by the emitter, the ones having negative Wigner functions. The aim of this work is to deepen the understanding of the protocol fundamental working mechanism and identify its optimal working points. To this end, we employ two approaches: the Collision Model, which provides an analytical time-resolved description of the closed emitter–field dynamics, and the Virtual Cavity Method, a powerful open-quantum system method, which allows for direct extraction of the states of selected modes of the field scattered by the emitter. The thesis compares and combines the predictions of the two models, evaluate their consistency and limitations, and explore how system parameters, such as driving strength, time-bin mode duration, and field configuration, affect the degree of Wigner negativity. Given the relevance of non-classical resources, the results discussed in this work can provide an interesting contribution to the development of quantum technologies.

P075

Diamond nanoneedles as a platform for multimodal and multifunctional sensing

Elena Filonenko
University of Eastern Finland

Track: Quantum Optics, Photonics, Sensing & Metrology

Abstract

Color centers in diamond provide several sensing mechanisms that can be combined within a single nanoscale structure [1]. Single-crystal diamond nanoneedles are particularly attractive because their elongated geometry creates spatially distinguishable regions, allowing different color-center populations to be separated within one nanostructure. Here, we investigate nanoneedles containing nitrogen-vacancy (NV) and silicon-vacancy (SiV) centers for multimodal thermometry and pH-sensitive photoluminescence sensing. Temperature was independently estimated from the temperature dependence of the NV^- zero-field splitting measured by optically detected magnetic resonance [2] and from the SiV^- zero-phonon-line position and linewidth measured optically [3]. From 23 to 40 °C, both approaches reproduced the applied temperature trend, enabling cross-validation of NV- and SiV-based readouts. The same nanoscale geometry also places a significant fraction of color centers close to the diamond surface, making their optical response potentially sensitive to the local chemical environment. In nanodiamonds, pH has been shown to influence NV charge-state conversion, resulting in photoluminescence fluctuations [4,5]. We therefore examined PL fluctuations in diamond nanoneedles over a broad pH range. Particle-associated blinking statistics depend on pH, with the strongest transient activity under acidic conditions, supporting the feasibility of PL fluctuations for pH sensing. Together, these results demonstrate multimodality through NV- and SiV-based thermometry and multifunctionality through temperature and pH sensitivity within the same diamond-nanoneedle platform.

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P076

Polarization squeezed light from two entangled two-level atoms

Najirul Islam
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Track: Quantum Optics, Photonics, Sensing & Metrology

Abstract

We theoretically demonstrated polarization squeezed light of the far-field radiation from two non-degenerate and entangled atoms. The total far-field is transverse in nature as the the observation direction is perpendicular to the total field. We construct the four standard Stokes operators of the total field projecting into two orthogonal polarization directions. We show that the far-field is polarization squeezed only when the the transition dipole moments are unequal. Within the single-excitation manifold, the the dipole becomes entangled and dipole asymmetry and geometry generates squeezing. These results show that non-classical polarization states can arise from a minimal two-emitter system without any non-linear medium.

Spin-Hamiltonian of the NV^- centre in diamond from first-principles calculations

P077

Alina Helena Sánchez Gallardo
University of Oulu

Track: Quantum Optics, Photonics, Sensing & Metrology

Abstract

The negatively charged nitrogen-vacancy (NV-) centre in diamond is a leading platform for quantum sensing and hyperpolarised magnetic resonance, due to its optically driven spin hyperpolarisation, long coherence times, and room-temperature operation. Quantitative modelling of spin polarisation transfer, decoherence and sensing contrast requires accurate spin-Hamiltonian parameters as essential input. We present a systematic first-principles study of the spin Hamiltonian of the NV- ground-state triplet. Convergence with respect to basis set, cluster size and electron correlation treatment is assessed simultaneously for all spin-Hamiltonian tensor components, establishing a reliable and reproducible computational protocol. The results are validated against established EPR and ENDOR benchmarks, confirming that the locally dense basis strategy and correlation methods deliver near-complete-basis accuracy at tratable computational cost across all cluster sizes. These validated parameters form the first stage of a multiscale simulation framework for hyperpolarised EPR and NMR in NV- systems. Ongoing work extends to a protocol to the excited triplet state, followed by a Lindbladian spin-dynamics modelling of the full optical cycle, including spin-selective intersystem crossing and photoinduced hyperpolarisation, targeting quantum sensing of individual nuclear spins in bulk diamond and at nanodiamond surfaces.

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