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Talks Monday, 23 February

Entanglement enhanced sensors of fields and forces

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N/A at printing deadline.

Loss tolerance for photons

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Entanglement is a key pillar of quantum physics and a resource for novel applications such as long-distance teleportation and measurement-based quantum computation. Equally important, it provides strong correlations that can be used to correct errors in quantum information protocols. For photonic qubits, the by far dominating error is the loss of the information carrier, the photon. The talk presents a promising route to overcome this error by redundantly encoding information into a highly entangled and loss-tolerant multi-qubit graph state. In the future, such states might become part of a memoryless quantum repeater.

Discovery of entanglement generation by elastic collision to realise the original Einstein-Podolsky-Rosen thought experiment

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The quantum effect of ‘entanglement’ was discovered in the 1935 thought experiment by A. Einstein, B. Podolsky and N. Rosen (‘EPR’). EPR did not discuss how to create the entanglement in their thought experiment. Here I add this part. What is required in the original EPR thought experiment is a simple elastic particle collision, an unbalanced mass ratio of e.g. 1:3 and initial states that are position and momentum squeezed, respectively. In the limiting case of infinite squeeze factors, the measurement of the position or momentum of one particle allows an absolutely precise conclusion to be drawn about the value of the same quantity of the other

particle. The EPR idea has never been tested in this way. I outline a way to do this with cold ions or atoms.

Precision Spectroscopy and Search for New Physics with Yb+ Ions

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N/A at printing deadline.

Multichannel Dicke Superradiance

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We develop and solve a Dicke superradiant model with two or more competing collective decay channels of tunable rates. Recent work analyzed stationary properties of multichannel Dicke superradiance using hydrodynamic mean-field approximations. We extend this with a symbolic quantum-trajectory method, providing a simple route to analytic solutions. For two channels, the behavior of the stationary ground-state distribution resembles a first-order phase transition at the point where the channel-rate ratio is equal to unity. For multiple competing channels, we obtain scaling laws for the superradiant peak time and intensity. These results unify and extend single-channel Dicke dynamics to multilevel emitters and provide a compact tool for cavity and waveguide experiments, where permutation-symmetric reservoirs engineer multiple collective decay paths.

Scaling Up Quantum Simulation Using Ion Chains

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Extended Abstract Online (ID 612)

Trapped ions have demonstrated the highest gate fidelities of any quantum platform. However, scaling to thousands of qubits while preserving qubit connectivity remains a challenge. Here, I present two routes to scaling ion-based quantum simulation based on linear ion chains. In one approach, mixed-species chains of 171Yb+ and

172Yb+ ions are trapped in a room-temperature microfabricated trap. Sympathetic laser cooling on a narrow transition using 172Yb+ ions counters the effects of motional heating and allows long gate operations on chains of up to 27 ions. Simultaneous cooling and combined digital/analog operations open the door to the simulation of spin-boson systems with engineered dissipation. In another approach, an optical cavity is integrated coaxially with a silicon micro-fabricated surface electrode trap for chains of individually addressable Ba+ ions. We align the cavity to the ion trap with sub-10 um precision and achieve finesse of about 5,000, corresponding to predicted peak single ion-photon cooperativity eta = 0.2. I will report on the mechanical resonances, initial bakeout, cavity performance, and ion trapping in this system. This ion-cavity system may be used to realize a coherent, single-photon interface between spatially separated ion chains with multi-kHz entanglement rates. The cavity mode can also form a blue-detuned optical lattice to suppress the motion of ions along the axial direction of the ion chain. This may allow individual addressing and controlled spin-spin interactions in chains up to 50 Ba+ ions with multiple internal states, with applications to quantum simulation.

Tailored States for Optical Atomic Clocks

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Optical atomic clocks represent the forefront of precision measurement, where quantum correlations and optimized interrogation strategies enable unprecedented frequency stability. In this talk, I will first discuss advances in GHZ-based protocols that enhance clock performance in regimes limited by spontaneous emission, showing that correlated measurements and nonlinear estimation strategies can achieve gains close to fundamental bounds. I will then present new results demonstrating that for atom numbers above 52, a different class of correlated spin states surpasses both GHZ and spin-squeezed states in approaching the asymptotic stability limit. In the second part, I will address laser-noise–limited regimes, where Bayesian frequency metrology provides a unified framework for incorporating frequency fluctuations and identifying optimal quantum states, measurement schemes, and estimation strategies. Together, these results outline a comprehensive approach to tailoring quantum resources for next-generation optical atomic clocks.

Precision measurements and many-body physics with laser-cooled molecules

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I will discuss two recent advances in the cooling and understanding of ultracold molecules. First, I will present our work on optical cycling and transverse laser cooling of a beam of fermionic 137BaF molecules. Their high masses and nuclear spins make these molecules sensitive probes for nuclear parity violation and the elusive properties of the weak interaction. However, the nuclear spins also lead to a quasi-closed cycling transition involving up to 750 levels, which significantly exceeds the complexity in other laser-cooled molecules. Optical cycling and cooling are facilitated through carefully designed optical spectra tailored to this molecular structure. Our results pave the way for efficient state preparation, detection, and cooling in a wide variety of precision measurements using this species and other similar species. Second, I will discuss numerical studies of strongly dipolar molecular Bose-Einstein condensates beyond the mean-field regime. These simulations reveal small droplets produced by strong dipolar interactions outside known stability regimes, including novel monolayer crystal phases. The simulations include realistic molecular interactions and therefore have direct relevance for current and future experiments.

Yang-Gaudin model: From Spin-Charge Separation to Luther-Emery liquid

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The low-energy excitations of a one-dimensional (1D) two-component repulsive ultracold atomic Fermi gas, i.e. Yang-Gaudin model, decompose into two collective motions (carrying either only spin or charge degree of freedom), a hallmark of the unique 1D spin-charge separation phenomenon. However, the 1D interacting fermions with attractive interactions exhibit novel Bardeen-Cooper-Schrieffer pairing states strongly dependent on polarization. The fully paired state (no external magnetic field) forms a Luther-Emery liquid, with an energy gap in spin excitations and gapless charge excitations. This talk discusses these starkly different features of 1D interacting fermions. Using a Feshbach resonance to access both repulsive and attractive interaction regions with 6Li atoms, we measured spin and charge dynamical structure factors via Bragg spectroscopy—and definitively observed spin-charge separation, consistent with nonlinear Luttinger liquids. Unlike repulsive interactions, we found spin waves propagate faster than charge density waves, revealing the pair-breaking nature of spin excitationsn and an inversion of the classic spin-charge separation in the attractive Fermi gas. Additionally, the RF spectra are consistent with an atom/molecule mixture stabilized by finite temperature and a spin-imbalance.

Talks Tuesday, 24 February

Quantum Simulation with Ultracold Atoms

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Extended Abstract Online (ID 539)

Manipulating quantum phenomena of microscopic particles to emulate novel states of matter and establish high-precision time standards promises to greatly advance future technological developments. Techniques involving ultracold atoms have formed a nexus between disciplines such as quantum information science, condensed matter physics, and quantum precision measurement, positioning them at the forefront of hot research areas in physics. In quantum simulation, systems comprising hundreds up to millions of atoms can be artificially created and controlled to mimic complex systems found in condensed matter physics and quantum field theory. This facilitates the validation or prediction of novel quantum phenomena, exploration of the underlying microscopic mechanisms, and fosters the next generation of technological and industrial revolutions. Utilizing small-scale and manageable ultracold fermionic systems, important unsolved models in condensed matter physics like the Fermi-Hubbard model can be simulated, aiming to acquire phase diagrams of strongly correlated fermionic systems at low temperatures. In this talk, I will introduce the latest developments in quantum simulation based on ultracold fermionic systems in USTC.

Utility Scale Quantum Computing

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N/A at printing deadline.

Light scattering and collective motion in tweezer arrays of polarizable objects

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Light is regularly used to trap polarizable objects like atoms, molecules, or dielectric nanoparticles in optical tweezers. Arrays of optical tweezers can now be used to arrange single atoms or nanoparticles in programmable structures, which can be used to engineer collective light scattering. At the same time, the scattered light interferes and induces an interaction mechanism known as light-induced dipole-dipole (LIDD) or optical binding forces, which results in collective motion. I will present two aspects of cooperative phenomena that arise from tunable light scattering in tweezer arrays of polarizable objects. Firstly, I will show how we can arrange single atoms, ground-state cooled in an optical cavity, to realize chiral Bragg scattering of light. Secondly, I will present how structured light gives rise to nonreciprocal LIDD interactions in the motion of dielectric nanoparticles.

Entanglement in quantum materials

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Extended Abstract Online (ID 587)

Entanglement is one of the most striking – and potentially most useful – phenomena in quantum physics. Over the past century, we've witnessed remarkable progress: from the discovery of the quantum nature of matter to the precise control and utilization of quantum states across a variety of platforms, with entanglement playing a pivotal role. Curiously, however, these advances have largely stalled at the doorstep of quantum materials – systems governed by the intricate interplay of multiple quantum degrees of freedom, and likely shaped in essential ways by their entanglement structure. In this talk, I will discuss recent developments in this field, focusing on the enigmatic "strange metal" state, which is uniquely suited to make progress.

Simultaneous entanglement distribution across a five-node, 275 km, deployed quantum network.

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Extended Abstract Online (ID 545)

The goal of quantum communication is to transmit quantum states between distant sites. The key aspect to achieve this goal is the generation of entangled states over long distances. Such states can then be used to faithfully transfer classical and quantum states via quantum teleportation. We will show a quantum network distributing quantum-memory compatible entanglement across five different physical nodes, across a total distance of 275 km over deployed fiber connections. We will show our current experiments where we produce memory-compatible 1324 nm polarization entanglement in two independent sources and simultaneously transmit it in two independent three-node sub-networks across Long Island, New York. We will also discuss on our efforts to unite these entanglement distribution sub-networks to form an entanglement swapping five-node quantum repeater testbed. Lastly, we will discuss our progress towards adding quantum memory capabilities to our quantum repeater testbed via using telecom-compatible rubidium vapor atomic ensembles.

High-Mass Matter-Wave Interference of Metal Clusters and Biomolecules

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Extended Abstract Online (ID 543)

The quantum superposition principle underpins modern quantum science and technology, yet its applicability to increasingly complex systems remains an experimental frontier. Matter-wave interferometry provides a stringent test by delocalizing massive particles over distances far exceeding their size. I report on a novel experimental platform that extends interferometry to a qualitatively new material class - large metal clusters - and present the first observation of quantum interference of sodium nanoparticles containing more than 7,000 atoms with masses exceeding 170 kDa [1]. The corresponding Schrödinger-cat state reaches a macroscopicity of $\mu = 15.5$, surpassing previous records by an order of magnitude and yielding the most restrictive bounds to date on generic macrorealistic modifications of quantum mechanics. I will also highlight applications in molecular metrology and current efforts toward quantum interferometry with biomolecules, including proteins, enabled by advances in source control and decoherence shielding. Looking ahead, deep-UV laser systems promise enhanced beam manipulation and detection contrast, enabling further scalability in mass and complexity and expanding the reach of matter-wave tests of quantum theory.

References

[1] S. Pedalino et al., (2025), arXiv:2507.21211 [quant-ph]

Reconfigurable many-body entanglement in cavity QED via collective dissipation and local driving

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Photon-mediated spin-spin interactions and collective decay are powerful tools in cavity QED, but typically only give access to a small fraction of Hibert space, i.e. they generate fully collective spin states. I'll discuss here a surprisingly versatile scheme for many-body reservoir engineering that relies solely on fully collective single-excitation decay, augmented with local Hamiltonian terms (ingredients all available in CQED). Our method is based on splitting the spin system into groups of sub- ensembles, and provides an easily tunable setup for stabilizing a broad family of pure, highly entangled states. This includes new kinds of states with metrological applications (e.g. Heisenberg-limited differential sensing with complete robustness against common mode noise), and also states that are of fundamental interest (e.g. states with symmetry-protected topological order including the spin-1 Affleck-Kennedy- Lieb-Tasaki (AKLT) state).

Dual-species quantum processors and quantum networks

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Reconfigurable arrays of neutral atoms have emerged as a leading platform for quantum science. Their excellent coherence properties combined with programmable Rydberg interactions have led to intriguing observations such as quantum phase transitions, the discovery of quantum many-body scars, and novel quantum computing architectures. Here, I will look forward to what is next for atom arrays. In particular, I am going to introduce a dual-species Rydberg array, that naturally lends itself for measurement-based protocols such as quantum error correction, long-range entangled state preparation, and measurement-altered many-body dynamics. The second atomic species is used as an auxiliary qubit to measure and control the primary species. In a first demonstration of this architecture, we use an array of cesium qubits to correct correlated phase errors on an array of rubidium data qubits [1]. Rydberg interactions between the two species then lead to novel regimes, including greatly enhanced resonant dipole interactions, that we use to demonstrate a two-qubit gate and quantum non-demolition readout [2]. Another crucially important step for atom arrays will be the scaling beyond a single processing module. I will describe how a modular quantum network architecture can look like and will present a node that combines large atom arrays with arrays of photonic interfaces at telecom wavelength [3].

Nanoscale Mirrorless Superradiant Lasing

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Extended Abstract Online (ID 511)

In this work, we predict collective 'free-space' lasing in a dense nanoscopic emitter arrangement where dipole-dipole coupled atomic emitters synchronize their emission and exhibit lasing behavior without the need for an optical resonator. At the example of a subwavelength-spaced linear emitter chain with varying fractions of pumped and unpumped emitters, we present a comprehensive study of this mirrorless lasing phenomenon. The total radiated power transitions from subradiant suppression under weak pumping to superradiant enhancement at stronger pumping, while exhibiting directional emission confined to a narrow spatial angle. At the same time multiple independent spectral emission lines below the lasing threshold merge towards a single narrow spectral line at high pump power. The most substantial enhancement and line narrowing occur when a fraction of unpumped atoms is present. We show that this leads to superradiant lasing near the bare atomic frequency, making the system a promising candidate for a minimalist active optical frequency reference.

Talks Wednesday, 25 February

New directions with cooperative atomic arrays

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What is the potential of dense—cooperative—emitter arrays? These arrays, already known for their use in metrology and quantum information as efficient waveguides and mirrors, are now being studied in alternative modes and geometries.

Optical Quantum Computers with Quantum Teleportation

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Extended Abstract Online (ID 569)

We succeeded in the realization of unconditional quantum teleportation in 1998 [1] Then, we invented the scheme of teleportation-based quantum computing in 2013 [2]. In this scheme, we can multiplex quantum information in the time domain and we can build a large-scale optical quantum computer only with four squeezers, five-six beam splitters, and two optical delay lines [3]. We built a real machine of optical quantum computer in Riken and put it on the cloud [4]. We will work on a neural network and Shor's algorithm with the real machine.

References

[1] A. Furusawa et al., Science 282 706 (1998) ~

[2] S. Yokoyama et al., Nature Photonics 7 982 (2013)

[3] W. Asavanant et al., Science 366 373 (2019)

[4] S. Yokoyama et al., arXiv:2509.06255 [quant-ph]

From Surface to Bulk: Cooper Pairing in a Mesoscopic Fermi Gas

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Fermionic pairing underlies diverse many-body phenomena, from superconductivity to nuclear structure. In finite systems, the discrete spectrum and limited particle number qualitatively modify pairing correlations [1,2]. We experimentally explore these effects using a two-dimensional Fermi gas of ultracold atoms, where tunable interactions and atom number allow us to trace the crossover from mesoscopic to bulk-like pairing. Using spin-resolved single-atom imaging combined with our recently implemented matterwave magnification technique [3], we obtain in-situ access to pair correlations in real space. In the weakly interacting regime, we observe a pronounced enhancement of correlations near the system's edge, reminiscent of surface pairing in nuclei. As interactions increase, this edge enhancement evolves into a uniform profile, signaling the emergence of bulk-like Cooper pairing. Our results reveal how confinement reshapes fermionic pairing beyond the standard BCS framework.

References

[1] J. Bardeen, L. N. Cooper, and J. R. Schrieffer, Phys. Rev. 108, 1175 (1957).

[2] P. W. Anderson, J. Phys. Chem. Solids 11, 26 (1959).

[3] S. Brandstetter et al., Phys. Rev. Lett. 135, 103401 (2025).

Collective light matter interactions in free-space atomic ensembles

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The understanding of the cooperative emission of light by an ensemble of atoms in free space has beed an outstanding problem of atomic physics for decades. This driven-dissipative many-body system poses an outstanding challenge to theory and requires dedicated experiments. I will present experimental results from our group where we study the cooperative interaction of ensembles of cold atoms in free space with resonant radiation. First, by measuring the photons radiated by an atomic cloud that is resonantly driven by a laser, one can observe cooperative spontaneous emission, i. e. superradiance and subradiance and characterize the field collectively radiated. Second, by using the tools of single-atom manipulation and readout, one can measure the effect of cooperative scattering by an ordered array, now at the single atom level to unravel the microscopic mechanisms behind collective effects.

False Vacuum, Hot Bubbles and other Ferromagnetic Stories

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Extended Abstract Online (ID 546)

Ultracold atomic mixtures can simulate quantum phenomena, including tunable ferromagnetic across first- and second-order phase transitions. Our experiments reveal bubble formation from metastable states, confirming predictions of False Vacuum Decay, with further investigations into temperature effects and bubble dynamics in flat potentials.

Exploring unknown regimes in quantum simulators with interpertable AI

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Extended Abstract Online (ID 547)

Quantum simulators enable the exploration of complex many-body physics beyond classical computation, but their interpretation is often hindered by limited and noisy observables. In this talk, I will show how interpretable machine learning can overcome this challenge. Using a variational autoencoder (VAE) framework, we extract meaningful physical parameters directly from experimental data, without supervision or prior knowledge of the system. Applied to Rydberg atom arrays, the method autonomously uncovers the phase structure and even reveals a previously unnoticed "corner-ordered" regime, for which we derive an order parameter via symbolic regression. The same pipeline, used on interference data from tunnel-coupled Bose gases realizing the sine–Gordon model, identifies relevant control parameters and detects solitonic excitations after quenches. Together, these results illustrate how interpretable ML can act as a discovery tool, unlocking new physics in quantum simulators.

Talks Thursday, 26 February

Exploring quantum computing frontier with neutral atom system

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We will discuss recent advances in realizing programmable quantum systems using neutral atom arrays excited into Rydberg states. These systems allow control over several hundred qubits in two dimensions and the exploration of quantum algorithms with both physical and encoded logical qubits and quantum error correction techniques. Recent experiments using neutral atom systems have redefined this exciting scientific frontier of quantum computing.They herald the advent of early error-corrected quantum computation and chart a path towards large-scale logical processors. Examples of emerging scientific directions, in areas ranging from universal fault tolerant quantum processing and topological spin liquids to lattice gauge theories and quantum gravity will be discussed.

Quantum Simulations with Ultracold Atoms in and Out-of-Equilibrium

Immanuel Bloch
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In my talk, I will discuss recent progress on quantum simulations using bosonic and fermionic atoms in optical lattices and optical tweezers. Next to outlining progress on rapid-cycle time quantum gas microscope experiments for the exploration of Fermi-Hubbard physics and pseudogap physics, I will also present results on large-scale quantum simulations using constrained Bose-Hubbard models for engineering exotic quantum phases of matter.

Cooling of an Optically Levitated Nanoparticle via Measurement-Free Coherent Feedback

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We demonstrate coherent, measurement-free optical feedback control of a levitated nanoparticle, achieving phonon occupations down to a few hundred phonons. Unlike measurement-based feedback, this all-optical scheme preserves the correlations between mechanical motion and the feedback signal. Adjustment of the feedback phase and delay provides precise and tunable control over the system dynamics. The ultimate cooling performance is currently limited by phase noise, which we analyze within a theoretical framework that outlines the constraints and prospects for reaching the motional ground state. Our results establish coherent feedback as a powerful tool for quantum control of levitated systems, extending beyond center-of-mass cooling.

Does noise help a (quantum) search?

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Efficient retrieval of information from a database is a core operation in our digital society. Quantum physics holds the promise for a definite speedup with respect to existing classical search algorithms. Achieving such speedup, however, requires an outstanding degree of control of the quantum dynamics of systems of large size. This involves suppressing and correcting errors caused by the inevitable action of the external environment. In the life sciences, search strategies are optimised to perform in dynamically changing environments. Adaptability is essential for successfully retrieving information and resources. In this talk, we will discuss these contrasting paradigms and analyse the circumstances in which an external environment could enhance the efficiency of, or even accelerate, a quantum search.

Quditology

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I motivate and provide a brief overview of qudits, which extend qubits beyond quantum binary to higher numerical radices, including both theoretical and experimental considerations, followed by a summary of state-of-the-art. Then I discuss my own collaboration on experiments to create Schrödinger cat states of a nuclear high-spin qudit in silicon and error correction in such systems.

Necessary and Sufficient Conditions for Universality with Local Quantum Control

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Suppose you have a quantum system of n qubits. Suppose also that you can control each of those qubits locally in an arbitrary (unitary) fashion. What additional operations are required to be able to perform any unitary on the whole system? In this presentation, we consider sets of Hamiltonians that define these “additional” operations and provide several sufficient conditions on these sets for ensuring that arbitrary unitary evolution is possible. For certain sets of Hamiltonians, these conditions are also necessary. We comment on the consequences for quantum computation, in particular regarding circuit compilation.

Engineering atomic energy levels for mescoscopic atom-light interactions

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Cold atoms are excellent samples for controlled atom-light interactions. Disorder often plays a detrimental role is large samples. The goal of our research is to study specifically disorder induced phenomena, as for instance Anderson localisation of light. It has been shown that the near field dipole-dipole interactions can be detrimental for an Anderson type phase transition for light in three dimensions. However, appyling specific energy shifts on the excited stats might allow to mitigate the near field dipole-dipole terms. I will discuss experimental results using an auxillary excited state to induce effective magnetic fields, which can be used for so-called diagonal disorder induced localisation as well as for magnetic field controlled localisation.

Monitored Quantum Matter

Michael Buchhold
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Understanding and actively shaping quantum entanglement in many-body systems is a key challenge for modern quantum technologies. Recently, monitored quantum dynamics — quantum dynamics with mid-circuit measurements — has emerged as a powerful tool for harnessing entanglement in NISQ devices and simulating non-equilibrium dynamics in condensed matter systems. In this talk, I will discuss our recent understanding of entanglement in monitored quantum dynamics from the viewpoint of emergent many-body phases and universality. Monitored dynamics generate wave functions with robust entanglement structures, which depend only on global properties such as symmetry and dimensionality, thereby defining entanglement phases of monitored quantum matter. We anticipate a symmetry classification of monitored matter akin to equilibrium quantum matter in Hamiltonian systems, which I will introduce using exemplary systems in one and two dimensions. I will also highlight our recent analytical and numerical advances and how they can be applied to engineer entanglement, for instance, in adaptive quantum circuits and driven quantum materials.

Controlling the dynamics of cold atomic gases via the coupling to a dissipative cavity

Corina Kollath
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Quantum gases in optical cavities have shown many exciting phenomena as the self-organization into superradiant phases. Additionally many complex phases have been predicted to be realizable in these systems reaching from topologically interesting phases to glass like phases. The theoretical treatment of these systems is very difficult due to the presence of the long range coupling of the cavity to the atoms and fluctuations need to be critically taken into account. We investigate bosonic atoms on a lattice and coupled to an optical cavity using many-body adiabatic elimination technique and exact matrix product state methods to capture the global coupling to the cavity mode and the open nature of the cavity. We simulate the spreading of correlations and discover the crossover between a light-cone dominated and a supersonic spreading of the correlations.

Talks Friday, 27 February

Diamond nanophotonic light-matter interfaces for quantum networking

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In this presentation I bridge ongoing work and proposed concepts in the control, analysis and engineering of single spin defects in diamond nanostructures for applications in quantum networking.

Semiconductor Spin Shuttling for High-Speed Quantum Gates and Reconfigurable Connectivity

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Extended Abstract Online (ID 531)

High-connectivity architectures, essential for quantum error correction (QEC), can be realized in semiconductors by physically shuttling spin qubits, leveraging established fabrication for large-scale integration. In this work, we use conveyor-mode transport, where gate voltages create traveling potentials in a Si/SiGe quantum dot array, to demonstrate several advancements. We first show high-fidelity (99.5%) spin shuttling over effective 10 μm and 99% CZ gate fidelity between mobile qubits. Next, we harness the shuttling dynamics itself for computation, realizing a 12 ns Hadamard gate (99.88% fidelity) and selectable CZ/CX gates within a single shuttling step. Finally, we introduce a reconfigurable bus architecture for non-nearest-neighbor connectivity, which we use to perform a four-way quantum non-demolition (QND) parity readout, a key QEC building block. These results elevate spin shuttling from mere transport to a versatile tool for high-speed control and scalable quantum processors.

Spin Resonance Spectroscopy with Free Electrons

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Coherent spin resonance methods such as nuclear magnetic resonance and electron spin resonance spectroscopy have led to spectrally highly sensitive, non-invasive quantum imaging techniques. Here, we will present a spin resonance spectroscopy approach developed for transmission electron microscopy [1–3] and will explain different techniques to sense with electrons for microwave manipulated spin states of the sample. This could enable state-selective observation of spin dynamics on the nanoscale and indirect measurement of the environment of the spin systems, providing information on, for example, atomic structure, local chemical composition and neighbouring spins.

References

[1] P. Haslinger, S. Nimmrichter, and D. Rätzel, Spin Resonance Spectroscopy with an Electron Microscope, Quantum Sci. Technol. 9, 035051 (2024).

[2] A. Jaroš, J. Toyfl, A. Pupić, B. Czasch, G. Boero, I. C. Bicket, and P. Haslinger, Electron Spin Resonance Spectroscopy in a Transmission Electron Microscope, Ultramicroscopy, 114224, (2025).

[3] A. Jaroš, M. S. Seifner, J. Toyfl, B. Czasch, I. C. Bicket, and P. Haslinger, Sensing Spin Systems with a Transmission Electron Microscope, ArXiv 2503.06761 (2025).

Building a solid-state thorium nuclear clock

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Thorium-229 is the only known nucleus with a laser accesible excited state. This isomer or long-lived nuclear excited state is suited to build a clock out of. A clock built out of a nucleus would be a probe for new physics, and would be less sensitive to external perturbations. A solid-state clock has great potential for applications, as miniaturization might be achievable. The interaction of the nucleus with its surroundings can be exploited and possibly engineered to build a solid-state nuclear clock. By using the temperature dependence of different hyperfine components of the nucleus-crystal, laser induced quenching of the nucleus and two photon excitation a new type of clock can be engineered ready for measurements in fundamental physics and applications.

N/A at printing deadline

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Fast and Error-Correctable Quantum RAM

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Extended Abstract Online (ID 621)

Quantum devices can process data in a fundamentally different way than classical computers. To leverage this potential, many algorithms require the aid of a quantum Random Access Memory (QRAM), i.e. a module capable of efficiently loading large datasets onto the quantum processor. However, a realization of this fundamental building block is still outstanding due to many crucial challenges, including incompatibility with current quantum hardware and quantum error-correction. In our work, we develop a QRAM design, that enables fast and robust QRAM calls, naturally allows for fault-tolerant and error-corrected operation, and can be integrated on present hardware. Our proposal employs a special quantum resource state that is consumed during the QRAM call, after being assembled efficiently in a dedicated module. This places a long missing, fundamental component of quantum computers within reach of currently available technology. In this talk, I will present the main ideas underlying our work, schematized in the figure below. First, I will give an introduction on the foundational role of QRAM across the quantum computing landscape, focusing on applications such as quantum search and factoring. Then, I will explain the key points of our work, and show how the long standing challenges that prevented the deployment of QRAM so far are overcome within our scheme. Concretely, I will discuss detailed blueprints and quantitative estimations for modern neutral-atom processors, where our proposed QRAM module finds a particularly efficient implementation.

Quantized vortex in an atomic Bose-Einstein condensate at Dirac point for honeycomb lattice

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Extended Abstract Online (ID 563)

See PDF abstract with ID 536 online.

Interplay between collective and individual dissipation in driven quantum systems

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Collective dissipation can generate useful quantum correlations, while ubiquitous individual decay destroys them. A natural question is how quantum correlations may still emerge at the generic interplay between these two competing processes. We address this by considering a driven system of many spins (“atoms") undergoing both collective and individual dissipation (“radiation"). In steady state and depending on drive, we find that the system exhibits a first-order phase transition and quantum bistability: its quantum state is a mixture of two many-body states associated with the two competing decay processes. Accordingly, one of these states closely resembles a correlated “coherently radiating spin state" (CRSS) — the solution of purely collective dissipation — exhibiting spin-squeezing entanglement, while the other is a separable state. We predict dynamical switching between the two stable states, manifest as many-body quantum jumps in the various observables of spin and radiation. Macroscopically, the switching rate tends to vanish and the system can reside in a correlated CRSS for long times. This reveals the mechanism by which correlated dissipative physics emerges at the presence of decorrelating individual decay, opening a path for unlocking collective dissipation phenomena in realistic quantum platforms and applications. We discuss consequences for experiments in collective radiation.

Self-Induced Superradiant Masing

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In cavity QED, particularly superradiance, emitters are typically treated as independent, interacting only through the shared cavity mode. Direct dipole-dipole interactions are instead often regarded as detrimental, causing decoherence and subradiance. Here, we demonstrate a contrasting regime of superradiance in a hybrid system of nitrogen-vacancy center spins in diamond coupled to a superconducting microwave resonator [1]. After inversion [2], the spin ensemble emits a superradiant burst that leaves a spectral hole in the inversion profile. Unexpectedly, this is followed by a train of revival pulses that evolve into a sustained superradiant masing state lasting up to one millisecond. We show that dipole-dipole interactions within the spin ensemble actively refill the resonant spin population, enabling persistent collective emission. Large-scale simulations of one million spins confirm that dipolar coupling drives spectral-hole refilling, producing self-pulsed emission that transitions into a quasi-continuous superradiant regime. These results reveal a mechanism where emitter-emitter interactions provide the effective drive for collective coherence, opening pathways to solid-state superradiant masers with ultra-narrow linewidths.

References

[1] W. Kersten et al., Self-Induced Superradiant Masing, arXiv:2402.08537 (2024).

[2] W. Kersten et al., Triggered Superradiance and Spin Inversion Storage in a Hybrid Quantum System, Phys. Rev. Lett. 131, 043601 (2023).

Posters

Entangling remote qubits through a two-mode squeezed reservoir

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Extended Abstract Online (ID 609)

The distribution of entanglement across distant qubits is a central challenge for the operation of scalable quantum computers and large-scale quantum networks. Existing approaches rely on deterministic state transfer schemes or probabilistic protocols that require active control or measurement and postselection. Here we demonstrate an alternative, fully autonomous process, where two remote qubits are entangled through their coupling to a quantum-correlated photonic reservoir. In our experiment, a Josephson parametric converter produces a Gaussian, continuous-variable entangled state of propagating microwave fields that drives two spatially separated superconducting transmon qubits into a stationary, discrete-variable entangled state. Beyond entanglement distribution, we also show that superconducting qubits can be used to directly certify two-mode squeezing, with higher sensitivity and without the need for calibrated noise-subtraction. These results establish networks of qubits interfaced with distributed continuous-variable entangled states as a powerful new platform for both foundational studies and quantum-technology relevant applications.

Experimental Demonstration of Electron-Photon Entanglement

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Extended Abstract Online (ID 583)

Entanglement [1] is a phenomenon which lies at the heart of quantum mechanics and provides key advantages to quantum optics experiments and applications, which are nevertheless limited by the nature of the particles used. The control of free electrons has revolutionised classical imaging techniques through the introduction of the transmission electron microscope (TEM), a powerhouse of atomic-resolution imaging and analysis. However, until recent experimental developments [2],[3], evidence of entanglement in the TEM has remained elusive. Here, we demonstrate the presence of entanglement in position and momentum between an electron and the coherent cathodoluminescence (CL) photon that it emits upon passage through a thin membrane sample [2]. We implement coincidence (ghost) imaging in a TEM [4], using a single photon counter and a spatially-resolved Timepix3 electron camera to study single electron-photon pair correlations [5]. With our setup, we are able to form an image of an object placed outside the TEM, in either the image plane or momentum plane of the photon path. From our coincidence images, we derive the joint uncertainty in both position and momentum spaces. The product of these two joint uncertainties violates the classical uncertainty bound [6] by more than 20 standard deviations: thereby demonstrating the presence of entanglement between the electron-photon pair, in the continuous variables of position and momentum. Further prospects enable the use of the same setup to test electron-photon correlations against stricter entanglement bounds or in discrete variables (e.g. [7]). This demonstration provides a pathway for the introduction of electron-photon pairs into quantum imaging techniques to exploit the unique and complementary properties of these two particles.

References

[1] A. Einstein, B. Podolsky, N. Rosen, Phys. Rev., 47, 10 (1935).

[2] A. Preimesberger, S. Bogdanov, et al., arXiv:2504.13163, (2025).

[3] J.-W. Henke, H. Jeng, M. Sivis, C. Ropers, arXiv:2504.13047 (2025).

[4] S. Bogdanov, A. Preimesberger, et al., arXiv:2509.14950 (2025).

[5] A. Preimesberger, et al., Phys. Rev. Lett., 134, 9 (2005). [

[6] S. Mancini, et al., Phys. Rev. Lett., 88, 12 (2002).

[7] P. Rembold, et al., Quantum Sci. and Tech., 10, 4 (2025).

An atomic array with strong cavity coupling

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The efficient generation of many-body entangled states is a key challenge for enabling useful quantum technologies. In most ultra-cold neutral atoms experiments manipulating single particles, entanglement is created by processes with limited range, such as contact, Rydberg or dipolar interactions. However, if one wants to efficiently create many-body states with non-local entanglement, like GHZ-states, the interactions between the atoms should also be inherently non-local. This can be realized via photon-mediated interactions, by strongly coupling atoms to an optical cavity. Specifically, we trap Rubidium atom in optical tweezers inside a high-finesse fiber cavity. Using the control and strong confinement provided by the tweezer traps, we are able to position the atoms accurately within the optical mode of the cavity and to maximize the coupling between the atoms and the light, thus achieving a strong single-atom cooperativity of 80. Using this platform we are aiming to prepare and study highly entangled state between the atomic qubits.

Programmable quantum simulator with 2D ion crystals

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Extended Abstract Online (ID 566)

Trapped ions are a versatile platform for quantum simulation of spin models due to their good coherence properties, the possibility to induce variable-range spin-spin interactions as well as the ease of site-resolved single-particle control and readout. We make use of a modified design of a linear Paul trap, which allows for trapping and cooling 2D crystal with up to 100 Ca^{*} ions, and implemented a programmable quantum simulator with flexible global and local control tools. Spin-spin interactions (Ising and XY-type) with variable interaction range are engineered by coupling the spins and the collective modes of motion via a stimulated Raman transition of a long-lived ground-state qubit. Using tightly focused laser pulses, we are able to independently control each particle state, and to create entanglement between arbitrary pairs of ions. We show that it is possible to combine multiple single particle unitary rotations and two-qubit entangling gates with a spin-spin interaction model of choice, thus qualifying our platform as a programmable quantum simulator. This paves the way to explore complex dynamics of entangled states in a lattice of spins.

Ghost Imaging with Free Electron-Photon Pairs

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Extended Abstract Online (ID 592)

Coincidence imaging, also known as ghost imaging, is a technique that exploits correlations between two particles to reconstruct information about a specimen. The particle that relays the spatial information about the object remains completely non- interacting, while the particle used to probe the object is not spatially resolved. While ghost imaging has been primarily implemented on photonic platforms, it be- comes particularly intriguing when applied to particles with fundamentally different properties, such as massive, charged electrons and massless, neutral photons, especially considering the role of both particles as cornerstones of highly advanced microscopic platforms. Utilizing a custom-built free-space cathodoluminescence setup integrated within a transmission electron microscope (see Fig. 1), we demonstrate electron–photon ghost imaging of complex patterns with a spatial resolution down to 2 μm. These advances have also enabled the first experimental demonstrations of entanglement between photons and free space electrons.

Dual-Species Atom Array Quantum Processors

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Reconfigurable arrays of neutral atoms have emerged as a leading platform for quantum science. Their excellent coherence properties combined with programmable Rydberg interactions have led to intriguing observations such as quantum phase transitions, the discovery of quantum many-body scars, and novel quantum computing architectures. Here I will give and overview on the dual-species Rydberg array experiments in the BernienLab. This novel platform is naturally suited for measurement-based protocols [1] such as quantum error correction, long-range entangled state preparation, and measurement-altered many-body dynamics. Furthermore, Rydberg interactions between the two species then lead to novel regimes, including greatly enhanced resonant dipole interactions, that we use to demonstrate a two-qubit gate and quantum non-demolition readout [2].

References

[1] Singh, Bradley, Anand, Ramesh, White, Bernien, Science 380, 1265 (2023).
[2] Anand, Bradley, White, Ramesh, Singh, Bernien, Nature Physics 20, 1744 (2024).

Non-reciprocal dynamics in exactly solvable interacting open system

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Extended Abstract Online (ID 529)

Exact solutions for strongly correlated systems are scarce - especially when introducing coupling to an external environment - and often require heavy analytical machinery. Here, we investigate a 1D open quantum system featuring long-range interactions, supplemented with incoherent loss and gain within the Lindbladian framework. We establish the exact solvability of the equations of motion of this model and we show that the interplay between non-reciprocity and interactions qualitatively reshapes both the propagation and decay dynamics of the excitations. We provide compact analytic expressions and diagnostics that quantify directional and interaction-tuned propagation under periodic boundary conditions, establishing a minimal, exactly solvable platform for interaction-driven, non-reciprocal many-body dynamics.

Universal dynamics of 3D Bose gases near the superfluid transition in the collective scattering regime

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Extended Abstract Online (ID 614)

Understanding the many-body dynamics of a quantum system after a quench is a central challenge in modern physics. In particular, quantum gases quenched across a phase transition evolve toward so-called nonthermal fixed points, characterized by a critical slowing down and a spatio-temporal scaling of correlations with universal exponents. Recently observed experimentally, this behavior extends the concept of universality to nonequilibrium systems. In our work, we use a quantum kinetic framework to describe collective scattering that takes place in highly occupied spectral regions. We then theoretically study three-dimensional Bose gases suddenly cooled across their superfluid transition. For weak quenches, we recover early-time inverse and direct energy cascades that are characteristic of weak turbulence where collective scattering is negligible. For strong quenches, collective scattering dominates, thus modifying the dynamical exponents and amplifying the bidirectional nature of the cascades. Our work shows that there exists a crossover between two dynamical universality classes, which is entirely controlled by the depth of the quench.

Optimal Quantum States for Frequency Estimation Limited by Spontaneous Emission

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Extended Abstract Online (ID 599)

We investigate ultimate bounds for frequency estimation with an ensemble of qubits subject to local spontaneous decay. For that purpose, a numerical maximization of the quantum Fisher information (QFI) over the initial state of the ensemble is carried out. For different numbers N of qubits, the QFI is maximized by very different state classes. In the regime of small N, unbalanced GHZ states with a correlated measurement and a nonlinear estimator perform close to optimal. Above a critical number of qubits, the QFI can be maximized by spin Gottesman-Kitaev-Preskill (Spin-GKP) states, which are the compact phase space analogues of the GKP states known from quantum error correction with a harmonic oscillator. The Spin-GKP states show a comb structure in phase space, and the performance of different phase space lattices is investigated. Spin-GKP-like states can also be created with a simple gate sequence. Two one-axis twisting gates and a rotation can be used to create Spin-GKP-like structures around the equator of the Bloch sphere to reach QFI values close to the ultimate bounds.

Error correction for Rydberg blockade-based maximum weighted independent set embedding

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Extended Abstract Online (ID 558)

The Rydberg blockade [1] naturally maps the information of the unit ball maximum weighted independent set (MWIS) [2], which corresponds to the solution of a specific NP-complete graph-coloring problem, onto an optical-tweezer-arranged neutral-atom system. Because the Rydberg blockade is a distance-dependent feature, it imposes strong limitations on the graph geometry. Therefore, realizing arbitrary connectivity between atoms requires an additional process known as embedding [3]. By introducing gadgets, sets of auxiliary atoms, embedding strategies can effectively mediate interactions between arbitrary pairs of atoms. Recently, three embedding schemes have been proposed: parity-architecture [4], crossing-lattice [5], and quantum-wire embeddings [6]. These embeddings encode each logical atom in the joint state of several physical atoms using the Rydberg blockade, providing intrinsic protection against local noise. However, error correction remains challenging. To

address this, we develop an error correction algorithm for Rydberg-blockade-based embeddings. Our decoding algorithm leverages superatoms, Rydberg-blockaded clusters allowing only one excitation. By counting excitations, the algorithm detects local error clusters and applies corrections when a unique solution exists; otherwise, it expands the clusters to ensure global consistency. Under an independent and identically distributed (i.i.d.) noise model, our cluster-based error correction algorithm exhibits a critical threshold. Moreover, it outperforms the previous post-processing approach, the Ebadi22 greedy algorithm [7]. Unlike conventional error correction methods, our approach leverages the intrinsic properties of the Rydberg platform and provides hardware-friendly insights that help bridge the existing gap between quantum hardware and software.

Damping of phonons in one-dimensional Bose gases

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Extended Abstract Online (ID 598)

Collective excitations in 1D integrable systems are expected to propagate almost without dissipation. Thermal fluctuations and deviations from linear dispersion are predicted to introduce subtle mechanisms of damping even in the deep 1D regime. In our experiment we directly excite phonon modes in a weakly interacting 1D Bose gas and study their time evolution. We prove the quantitative agreement between experiment and hydrodynamic prediction and establishes phonon–phonon scattering as the dominant relaxation mechanism for low-momentum excitations in near-equilibrium 1D quantum fluids.

Benchmarking the Cumulant Expansion Method using Dicke Superradiance

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Collective superradiant decay of a tightly packed inverted quantum emitter ensemble is among the most intensely studied phenomena in quantum optics. Since the seminal work of Dicke more than half a century ago, a plethora of theoretical calculations in quantum manybody physics have followed. Widespread experimental efforts range from the microwave to the X-ray regime. Nevertheless, accurate calculations of the time dynamics of the superradiant emission pulse still remain a challenging task requiring approximate methods for large ensembles. Here, we benchmark the cumulant expansion method for describing collective superradiant decay against a newly found exact solution. The two cumulant expansion methods converge well for the timing and magnitude of peak emission but struggle to accurately model long-term population dynamics. For few emitters, the individual spin-based approach performs better, while at higher emitter numbers both methods give similar results yet fail to reliably converge to the numerically exact results. Odd-order expansions behave unphysically, and over longer times both methods overestimate the remaining population. While numerically fast and efficient, cumulant expansion methods need to be treated with sufficient caution when used for long-time evolution or reliably finding steady states.

De-excitation dynamics of a nuclear ensemble after strong impulsive excitation

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Extended Abstract Online (ID 601)

Mössbauer nuclei are an extreme platform for quantum optics because of their narrow transitions in the x-ray regime. These narrow transitions feature long lifetimes, but on the other hand also allowed to only study single excitations for decades. This has recently changed with first experiments at X-ray free electron lasers, where now multiple photon excitations and the subsequent dynamics as well as nuclear clock transitions can be studied. This technological progress immediately raises the question whether there are new effects expected depending on the number of resonant photons. Yet, a theoretical modeling of the decay dynamics of the interacting nuclear ensemble is still an open challenge. Therefore, we derived a toolbox which is capable of efficiently modeling large nuclear ensembles for arbitrary degrees of excitation, with which we can study new effects in the de-excitation dynamics as well as finite size effects. Here, I will comment briefly on our experimental progress and and discuss the findings of our theoretical simulations.

Anti-Critical Metrology

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Critical quantum metrology exploits the fact that, near a quantum phase transition, the quantum Fisher information can grow without bound, thereby enhancing the attainable precision in parameter estimation. This enhancement, however, is traditionally tied to a vanishing energy gap, which drives the characteristic timescales to infinity and hinders practical applications. Here we show that in interacting quantum systems this link is much more subtle: an improved sensitivity does not necessarily require a closing energy gap and, what is perhaps the most surprising, a growing quantum Fisher information does not necessarily lead to an enhanced precision. Exploiting this insight, we introduce an anti-critical metrology scheme that achieves enhancements of the precision while simultaneously increasing the energy gap. We illustrate this principle with the quantum Rabi model, revealing a novel route to metrological advantage in interacting quantum systems without the critical slowdown.

Strong three-photon correlations from coupled quantum emitters

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Extended Abstract Online (ID 605)

The interaction between photons and a highly nonlinear optical medium has the potential to create a strongly correlated many-body photonic system. Photon-photon interactions can be mediated by individual atoms that are coupled to the light field. To explore the regime of many-body quantum optics, it is necessary for many photons to interact simultaneously. However, scaling the nonlinear photonic response to higher-order correlations poses a significant challenge. In this study, we realize a strongly correlated photonic system that can be controlled by the number of quantum emitters involved in the interactions. We demonstrate that the scattering of two coupled quantum dots in a waveguide leads to enhanced three-photon correlations and suppresses lower-order contributions. As a result, the interaction with the collectively coupled system produces genuine three-photon correlations. These advancements could enable functionalities for photonic quantum gates and the generation of multipartite entangled states, while also opening up new possibilities for studying many-body physics with photons.

Directional emission from waveguide-coupled quantum dots with individual control

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Radiative coupling between quantum emitters leads to a range of spectacular emission phenomena such as super- and subradiance. Waveguide quantum electrodynamics (QED) allows the coupling of spatially separated emitters, which enables individual addressability. We investigate a pair of independently tunable quantum dots embedded in a bidirectional photonic crystal waveguide. Remarkably, the emitters are separated over 13 μm, yet they remain radiatively coupled. The coupling possesses a dispersive component that induces energy shifts of the collective states. By manipulating the relative driving phase using a spatial light modulator, we switch the emission direction from left to right. In addition, we observe direction-dependent photon statistics under continuous-wave excitation with single-photon emission to the left and photon-pair emission to the right. Using pulsed excitation, both emitters are fully inverted, leading to correlated photon-pair emission observed in time-resolved intensity correlations. Our results realize a novel implementation of chiral quantum optics with waveguide-coupled quantum dots and represent an important step toward scalable multi-emitter waveguide QED platforms.

Selective Preparation of Collective States via SUPER Excitation

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Extended Abstract Online (ID 541)

Here, for the first time, we utilize the Swing-UP of quantum EmitteR population (SUPER) excitation scheme to deterministically and efficiently populate the superradiant and subradiant states of two dipole-coupled quantum emitters at deep-subwavelength separation [1]. In particular, we theoretically show that this ultrashort excitation scheme, relying on two red-detuned time-overlapped Gaussian pulses, penetrates the system's electromagnetic environment to efficiently prepare target collective states. Importantly, even in the presence of a certain amount of environmental decoherence, specifically in quantum dots and molecules. This, in turn, opens possibilities to directly witness the signature radiative properties of superradiance and subradiance. Our scheme enables single-photon generation (with an optical cavity), which, in principle, could operate at elevated temperatures and which would be beneficial for quantum information processing.

References

[1] J. Kerber et al., arXiv:2508.19692 (2025).

Dipolar interaction in optically dense media: internal atomic structure matters

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Extended Abstract Online (ID 548)

This work presents a theoretical investigation of the spectroscopy of dense, cold atomic clouds composed of multilevel atoms. We focus on regimes where the internal atomic structure plays a crucial role in determining collective optical properties such as the collective Lamb shift (CLS) and the cooperative decay rate (CDR) — phenomena originating from interatomic dipole–dipole interactions and manifested in the excitation spectra of dense ensembles.

Optical Hyperfine Qudit Gates in Trapped Atoms

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Extended Abstract Online (ID 551)

We propose a fast, all-optical scheme for single-qudit control in alkaline-earth(-like) atoms operating in moderate to strong magnetic fields. Using optimized single-beam Raman transitions on the 1S0 to 3P1 line, neighboring hyperfine levels can be driven with high fidelity at rates higher than tens of kilohertz. The method enables universal qudit gates without oscillating magnetic fields, advancing nuclear spin control for quantum information applications.

Violating Bell's Inequality with Single-Photon Entangled States using Self-Referential Measurements

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Extended Abstract Online (ID 522)

In the early 1990s, it was suggested that a single photon split into two spatial modes could violate a Bell inequality [1], [2]. Previous implementations relied on local oscillators, raising concerns about the true origin of the correlations [3], [4], [5]. We demonstrate a CHSH violation without the need for local oscillators or post-selection, using two copies of a single-photon entangled state. Two indistinguishable photons are split on beam splitters and shared between Alice and Bob. In our self-referential scheme, one copy acts as the phase reference for the other. We achieve a Bell violation above the classical bound using two copies of separa-ble single-photon states, reaching 2.25 ± 0.02 without and 2.71 ± 0.03 with post-selection. This provides a simpler, oscillator-free route to device-independent quan-tum cryptography, where Bell violations certify secure correlations between distant parties.

Towards strongly interacting many-body states of dipolar spin mixtures in optical lattices.

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Extended Abstract Online (ID 584)

Ultracold erbium atoms offer a rich platform for exploring strongly correlated quantum phenomena due to their large spin manifold and strong dipolar interactions. We demonstrate a novel method for manipulating the spin population in bosonic erbium using a laser tuned to a clock-like transition at 1299 nm, enabling the preparation of arbitrary superpositions of spin states via sequences of Rabi-pulse pairs. Implemented in an optical lattice, this technique suppresses collisional effects, allows precise studies of spin-dependent scattering, and enables an accurate determination of the natural linewidth of 0.48(3) Hz.

Density-wave ordering of unitary Fermi gases loaded in a box trap

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Quantum degenerate gases provide a pristine environment to control and observe the underlying quantum many-body dynamics. Cavity quantum electrodynamics

(QED) in ultracold atomic gases, in particular, enable both a real-time readout of photons leaking out of the cavity and an in-situ observation of the atomic density profile. Here, we present the observation of density-wave ordering in unitary Fermi gases loaded in a box trap using two complementary observables: photons leaking out of the cavity and the modulation of the density profile in both the in-situ absorption and phase contrast image. The box trap allows for a cleaner environment to quantitatively understand the phase transition dynamics of density-wave ordering. We also discuss some possible applications of the digital micromirror device (DMD) used for engineering our box trap and phase-contrast imaging in characterizing spin-imbalanced Fermi gases strongly coupled to a cavity.

Effect of Coupling Geometries on the Multi-mode, Open Dicke Model

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Extended Abstract Online (ID 571)

In this theoretical work, we are investigating the multi-mode Dicke model in a 'nearest-neighbour' geometry, where there are M clusters of atoms and M-1 cavity modes arranged so that each cavity mode couples to two neighbouring clusters of atoms. In particular, we characterize the steady state solutions, and show that beyond the superradiant transition there are additional stable steady-state solutions, the number of which increases with the number of atomic clusters in the system. We show that some of these stable steady-state solutions correspond to persistent oscillations in the mean-field limit, and investigate the fate of these oscillations for finite sized clusters. Our work demonstrates that there is rich new physics possible when considering different coupling geometries in the multimode Dicke model.

Gaussian tomography in cold-atom simulators

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In cold-atom lattice experiments, measurements are always done in the number/occupation basis (detecting presence or absence of an atom). The goal of this work is to solve this problem in an experimentally friendly way (no local control, no extra tools). We find straightforward experimental protocols based on

non-interacting dynamics that allow one to extract currents and other charge off-diagonal observables regardless. Moreover, we show that one can estimate the entire non-interacting Hamiltonian efficiently by just studying quenches from a single initial state. This is based on work with Matt Kiser, Max McGinley and Bhavik Kumar contained in the two preprints arXiv:2510.23591 and arXiv:2510.233022

Photon number states via iterated photon addition in a loop

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Extended Abstract Online (ID 618)

The preparation of n-photon states, that is, the implementation of sources emitting a specific number of photons, is an important problem in many quantum optics and quantum information applications. In this work, we analyse the possibility of using an arrangement consisting solely of a periodic single-photon source, a beam splitter, mirrors, and a realistic photon detector. The setup consists of a loop in which we employ Hong-Ou-Mandel interference to achieve iterative photon addition. Its purpose is to generate an arbitrary n-photon Fock state probabilistically, conditioned by measurement results. These states exhibit strong non-classical behaviour. The literature typically proposes more complex schemes for their generation. In this work, we demonstrate that our arrangement composed only of passive linear optical elements, can generate up to four-photon states with reasonable fidelity and probability even with imperfect detectors. Our work also contributes to the better understanding of photonic interferometric loops which are important in photonic quantum computing.

Bio-inspired Nanoscale Stacked Ring Geometry for Efficient Excitation Transfer

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Extended Abstract Online (ID 520)

In photosynthesis, nature relies on light-harvesting (LH) complexes to efficiently capture and transport solar energy to the reaction center. Taking inspiration from the oligomeric geometry of biological LH2 complexes (about 6 nm in diameter), we utilized the quantum optical Lindblad master equation approach to theoretically propose and predict highly efficient asymmetric interlayer excitation energy transfer in a bio-inspired, larger ninefold stacked concentric ring geometry (diameter of 400 nm) [1]. This three-dimensional stacked configuration of two-level atoms enables a maximum of 100% excitation transfer via the darkest collective eigenmode, in particular from the sparse to dense ring layer, for certain choices of dipole orientations. Our approach provides a blueprint for proposing similar stacked geometries with different rotational symmetries. The proposed ring geometry is accessible by nanofabrication and could be realized in diverse physical platforms operated at cryogenic temperatures, where weak or controllable system-environment interactions can be achieved.

References

[1] A. Pal et al., New J. Phys. 27, 094101 (2025).

Chiral superfluorescence from perovskite superlattices at room-temperature

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Extended Abstract Online (ID 568)

Superfluorescence (SF) describes the enhanced radiation of coherent light from cooperatively coupled quantum emitters. While SF has been observed in several solid-state materials, the spontaneous generation of circularly polarized SF from chiral materials (chiral SF) has not been realized. Here, we report the first observation of chiral SF originating from edge states in large-area ($> 100\ \mu$m $\times$ $100\ \mu$m) vertically aligned quasi-2D chiral perovskite superlattices at room-temperature. Theoretical quantum optics calculations describe the transition from initially incoherent, unpolarized spontaneous emission to circularly polarized chiral SF, which changes sign depending on the handedness of the chiral material. Moreover, we show that both the intensity and degree of circular polarization of chiral SF can be modulated by a weak magnetic field. Our findings demonstrate an interplay between geometrical chirality and many-body quantum coherence, thereby revealing promising new directions for chirality-controlled quantum spin-optical applications at room-temperature.

Towards Scalable Adiabatic Quantum Algorithms for MIS

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Extended Abstract Online (ID 600)

Recent advances in neutral-atom quantum computers enable scaling their computation power toward solving large combinatorial optimization problems (COPs) [1,2]. Hybrid algorithms, combining classical and quantum computing, offer a promising path forward. This talk presents two hybrid adiabatic quantum computation (AQC) approaches for solving prototypical COP – finding the Maximum Independent Set (MIS) of a graph – on neutral-atom quantum annealers, potentially extending the reach to problem sizes beyond current capabilities. Our first algorithm utilizes mathematical graph properties to inflate the spectral gap of the Hamiltonian, which limits the complexity of traditional AQC. Even though finding the MIS of a graph requires, in principle, checking independent sets across the entire graph, we show that information regarding the local density of edges can be used to engineer the controls and accelerate the convergence towards the desired solution state. Secondly, we present a pulse optimization method for accelerating adiabatic control protocols [3]. Our method finds control pulses that keep the quantum system in its instantaneous ground state during the evolution. It is efficient, using gradient-free optimization, and robust, using analytic adiabatic solutions in the optimization cost function. To validate our results, we perform digitized adiabatic protocols on IBM's quantum cloud and run numerical simulations of Rydberg atom arrays.

References

[1] S. Ebadi, A. Keesling, et al., Science, 376(6598):1209–1215 (2022).

[2] K. Kim, M. Kim, et al., Scientific Data, 11(1):111 (2024).

[3] D. Turyansky, Y. Zolti, Y. Cohen, and A. Pick., arXiv:2507.09770 (2025).

Motion in Subwavelength Atomic Arrays: Polaron-Polaritons

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Extended Abstract Online (ID 573)

We study how atomic motion modifies the collective dipolar excitations and light–matter interactions of subwavelength atomic arrays. In the Lamb–Dicke regime, we derive an effective polaron–polariton description that captures correlated spin–phonon dynamics beyond previous "fast" and "frozen" motion approaches. Using both analytical polaron theory and numerical simulations, we show that: (i) excitation transport remains surprisingly robust against motion, even at low trap frequency, (ii) phonon emission can strongly boost decay of subradiant states as well as enable their excitation, (iii) the detrimental impact on the reflectivity of a 2D atomic mirror can be alleviated by changing the trap frequency, which moves phononic sidebands out of resonance , and (iv) in the presence of atomic recoil an array still radiates directionally when it is driven close to a phononic sideband. Our findings lay the foundation for analyzing motional effects in key applications and suggest new ways to harness subradiant modes and optomechanical effects in emerging experiments.

Parallel cryogenic setups for scalable quantum computation with surface ion traps

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Trapped-ion (TI) quantum systems are promising candidates for future quantum computing applications. TI devices based on macroscopic linear Paul traps are practically limited to a maximum of 30 ions. Microfabricated surface traps are an alternative approach that allow for improved scalability though modular design, integrated optics, and additional electronic trap layers. Here we present the implementation of parallel cryogenic setups—one rack-based, and one table-based—for rapid testing and characterization of such surface traps. Each setup features an independent cryostat able to cool to a base temperature of 5K within 12 hours. Trap integration is realized via a standardized socket interface, reducing trap exchange time to approximately 2 hours. The setups feature 128 (100) DC electrodes, 6 RF electrodes, 21 in-vacuum fibers for 40Ca+ wavelengths, and two independent resonators to enable concurrent axial and radial shuttling. The rack-based setup additionally features a novel hermetic interface to facilitate rapid swapping of vacuum chambers without venting, thus minimizing experimental downtime.

What can we know about a Quantum Many-Body System?

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Quantum Many Body Systems are at the basis of many Quantum Simulations. It is therefore of upmost interest to understand their information content and structure and how it can be manipulated and extracted or measured. One avenue, based on our understanding of quantum field theories, is based on correlation functions, which reveal the accessible structure [1] and their effective descriptions either directly [2] or through learning algorithms [3]. A different approach is through many-body tomography [4] which then allows to extract of von Neuman entropies. This allowed us to verify the area law for mutual information [5] in quantum many body systems. The tomography approach is limited to Gaussian effective models. Currently we are developing new model agnostic approaches, which allows to study also strongly correlated and topological systems [6,7]. Finally, I will ask the question what it takes to erase information in a many-body system and present our experiments probing Landauer's principle in the quantum many-body regime [8].

Characterising transport in a quantum gas by measuring Drude weights

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Transport properties play a crucial role in defining materials as insulators, metals, or superconductors. A fundamental parameter in this regard is the Drude weight, which quantifies the ballistic transport of charge carriers. In this work, we measure the Drude weights of an ultracold gas of interacting bosonic atoms confined to one dimension, characterising atomic and energy currents induced by applying a constant force and by joining two subsystems prepared in different equilibrium states. We demonstrate dissipationless transport, even in the presence of interactions and finite temperature, signifying ballistic propagation of conserved quantities corresponding to lowest order hydrodynamics. Our protocols facilitate systematic testing of non-ballistic, higher-order hydrodynamic terms and non-linear responses, finding both negligible within the scales probed. Our approach, built on minimal assumptions and detached from theoretical modeling, provides a robust and transparent framework for characterising transport in strongly correlated quantum matter, applicable in regimes where theory remains incomplete.

Machine learning using Gaussian Continuous Variable Quantum Optical Systems

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Certain machine learning algorithms represent some of the most promising applications of quantum computing in the near term. All proposals to date for implementing such algorithms using continuous variable (CV) quantum optical systems depend on the ability to perform non-Gaussian operations. However, these operations are difficult in current experimental platforms for CV computing. In this work, we present several Ansätze for implementing neural networks using Gaussian operations only, and that are thus amenable to implementation on current systems. In particular, these Ansätze are tailored to systems designed for CV measurement-based quantum computation. Consequently, several of these Ansätze can be implemented in an entirely optical fashion, i.e., using an all-optical teleportation protocol in lieu of the traditional protocol mediated by homodyne measurements. This latter feature may provide a practical advantage in computational time, due to the higher possible bandwidth for information processing that this optical implementation confers.

Entanglement-enhanced quantum sensing via optimal global control with neutral atoms in cavity

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Extended Abstract Online (ID 611)

We introduce a deterministic protocol for generating metrologically useful entangled states in medium-sized spin ensembles (up to 100 atoms) coupled to a common cavity mode. By combining a cavity-driven geometric phase gate, an analytic treatment of noisy quantum dynamics, and optimal control of laser pulses, our method enables precise unitary control within the symmetric Dicke subspace even in the presence of realistic decoherence. This approach offers a practical pathway to entanglement-enhanced quantum sensing with cold atoms in cavities and is adaptable to other spin–boson platforms.

Extracting pairs of time-bin entangled photons from resonance fluorescence

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Photon-photon entanglement and photon antibunching are fundamental manifestations of the quantum nature of optical light fields, but are typically regarded

as distinct phenomena. Here, we experimentally demonstrate that pairs of narrowband time-bin entangled photons can naturally be extracted from resonance fluorescence. We split the collected fluorescence of a single trapped atom using a 50:50 beamsplitter, resulting in strong temporal correlations between photons at the beamsplitter outputs. A time-bin coincidence between the two output modes then projects the photon state onto a maximally entangled Bell state. This entanglement is evidenced by violating the CHSH-Bell inequality as well as by reconstructing the density matrix of the photon pair. Importantly, we show that the entanglement persists both for weak and strong excitation of the emitter. Our results establish resonance fluorescence as an efficient source of time-bin entangled photon pairs, i.e., a practical and scalable resource for quantum communication and photonic quantum technologies.

Restoring thermalization in long-range quantum magnets with staggered magnetic fields

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Extended Abstract Online (ID 538)

Quantum systems with strong long-range interactions are thought to robustly resist thermalization because their energy spectra organize into a discrete number of multiplets. We show that this non-thermal behavior is surprisingly fragile to an experimentally ubiquitous perturbation: a staggered magnetic field. Using self-consistent mean-field theory and exact diagonalization, we reveal that the energy spectrum, while composed of discrete subspaces or multiplets, collectively forms a dense spectrum. For initial states at low to intermediate energies, the long-time average aligns with the microcanonical ensemble. However, for states in the middle of the spectrum the long-time average depends on the initial state due to quantum scar-like eigenstates localized at unstable points in classical phase space. Our results can be readily tested on a range of experimental platforms, including Rydberg atoms or optical cavities.

Realization of Fractional Fermi Seas

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The Pauli exclusion principle is a cornerstone of quantum physics. It governs the structure of matter. Generalizations of this principle, such as Haldane's generalized exclusion statistics, predict the existence of exotic quantum states with fractional Fermi sea (FFS) momentum distributions with uniform but fractional occupancies. Here, we report the experimental realization of fractional Fermi seas in an out-of-equilibrium one-dimensional Bose gas using holonomy cycles of the interaction. Remarkably, the resulting excited yet stable Bose-gas states exhibit Friedel-like oscillations, tell-tale signs of the underlying FFS. The stabilization of these states offers an opportunity to deepen our understanding of quantum thermodynamics in the presence of exotic statistics and paves the way to applications in quantum information and sensing.

Programmable quantum simulator with 2D ion crystals

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Extended Abstract Online (ID 582)

Trapped ions are a versatile platform for quantum simulation of spin models due to their good coherence properties, the possibility to induce variable-range spin-spin interactions as well as the ease of site-resolved single-particle control and readout. We make use of a modified design of a linear Paul trap, which allows for trapping and cooling 2D crystal with up to 100 Ca^{*} ions, and implemented a programmable quantum simulator with flexible global and local control tools. Spin-spin interactions (Ising and XY-type) with variable interaction range are engineered by coupling the spins and the collective modes of motion via a stimulated Raman transition of a long-lived ground-state qubit. Using tightly focused laser pulses, we are able to independently control each particle state, and to create entanglement between arbitrary pairs of ions. We show that it is possible to combine multiple single particle unitary rotations and two-qubit entangling gates with a spin-spin interaction model of choice, thus qualifying our platform as a programmable quantum simulator. This paves the way to explore complex dynamics of entangled states in a lattice of spins.

Dissipative Realisation of η-Pairing in Multimode Cavity QED

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Extended Abstract Online (ID 552)

Markovian dissipation has been predicted to lead to steady states with off-diagonal long-range η-pairing order in the Hubbard model. Building on this idea, we propose a concrete implementation using a Fermi gas confined in a two-dimensional optical lattice and coupled to a near-confocal, multimode cavity. This configuration enables site-resolved spin–photon coupling while suppressing photon-mediated long-range interactions characteristic of conventional cavity-QED systems. I will discuss how the proposed quadruple-Λ Raman coupling scheme can realise effective dissipation for the matter degrees of freedom and explore how multimode-mediated interactions can be tuned to access both Markovian and non-Markovian regimes of the dynamics. This work bridges theoretical advances in driven-dissipative quantum many-body physics with functionalities offered by the multimode cavity-QED platform, paving the way toward experimental realisations of a dissipatively stabilised long-range η-pairing order.

Interpretable representation learning of quantum data

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Interpretable machine-learning tools are playing an increasingly important role in quantum-science research. Our work presents a broadly applicable methodology that combines modern generative models with quantum many-body physics to learn compact and physically meaningful representations directly from raw, unlabelled snapshots of quantum experiments. Among interpretable models, variational autoencoders (VAEs) have gained considerable attention due to their ability to autonomously extract minimal and meaningful representations from complex datasets. However, existing applications of VAEs to quantum data have largely overlooked its intrinsic stochasticity. This omission is critical: if a VAE cannot accurately capture the underlying probability distribution of the data, it cannot produce meaningful representations. To address this, we propose two key adaptations that enable VAEs to properly account for the stochastic nature of quantum data: we reformulate VAE training as an explicit probability-distribution matching task and design an autoregressive decoder capable of faithfully representing quantum probability distributions. Using benchmark quantum spin models, we identify regimes where standard methods fail while the representations learned by our approach remain meaningful and interpretable. Applied to experimental data from Rydberg atom arrays, the model autonomously uncovers the underlying phase structure without access to prior labels, Hamiltonian details, or knowledge of relevant order parameters, highlighting its potential as an unsupervised and interpretable tool for the study of quantum systems.

Directional quantum scattering transducer in cooperative Rydberg metasurfaces

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Extended Abstract Online (ID 572)

We present a single-photon transduction scheme using 4-wave-mixing and quantum scattering in planar, cooperative Rydberg arrays that is both efficient and highly directional and may allow for terahertz-to-optical transduction. In the 4-wave-mixing scheme, two lasers drive the system, coherently trapping the system in a dark ground-state and coupling a signal transition, that may be in the terahertz, to an idler transition that may be in the optical. The photon-mediated dipole-dipole interactions between emitters generate collective super-/subradiant dipolar modes, both on the signal and the idler transition. As the array is cooperative with respect to the signal transition, an incident signal photon can efficiently couple into the array and is admixed into dipolar idler modes by the drive. Under specific criticality conditions, this admixture is into a superradiant idler mode which primarily decays into a specific, highly directional optical photon that propagates within the array plane. Outside of the array, this photon may then be coupled into existing quantum devices for further processing. Using a scattering-operator formalism we derive resonance and criticality conditions that govern this two-step process and obtain analytic transduction efficiencies. For infinite lattices, we predict transduction efficiencies into specific spatial directions of up to 50%, while the overall, undirected transduction efficiency can be higher. An analysis for finite arrays of N^2 emitters, shows that the output is collimated into lobes that narrow as $1/\sqrt{N}$. Our scheme combines the broadband acceptance of free-space 4-wave mixing with the efficiency, directionality and tunability of cooperative metasurfaces, offering a route towards quantum-coherent THz detection and processing for astronomical spectroscopy, quantum-networked sparse-aperture imaging and other quantum-sensing applications.

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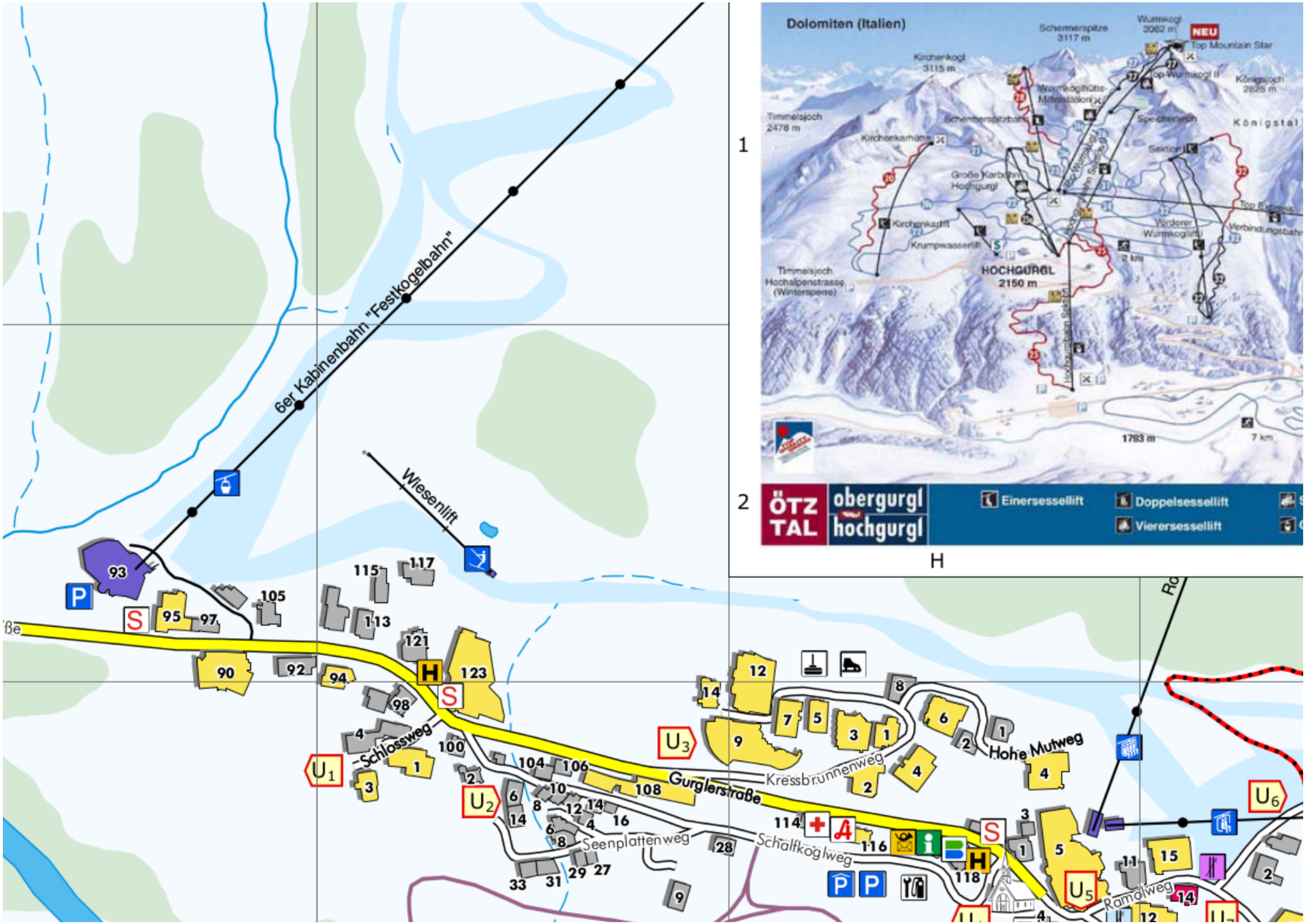
Notes



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Ramolweg
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Schermerspitze 3117 m
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			Quantum Optics	Quantum Austria Excellence	BeyondC SFB	Quantum II	Quantum III	
08:00 - 08:30			Intro		Woman's Breakfast (tbc)			
08:30 - 09:05	Invited		Polzik	Yu-Ao Chen	Yelin	Lukin	Schröder	return BUS
09:05 - 09:40	Invited		Rempe	Troyer	Furusawa	Bloch	Matsumoto	return BUS
09:40 - 10:00	Hot topic		Schnabel	Delic	Brandstetter	Meyer	Haslinger	
10:00 - 10:30	Coffee							
10:30 - 11:05	Invited		Mehlstäubler	Bühler-Paschen	Ferrier-Barbut	Morigi	Beeks	return BUS
11:05 - 11:25	Hot topic		Holzinger	Figueroa	Zenesini	Sanders	Blatt	return BUS
11:25 - 11:45	Hot topic		Cetina	Gerlich	Munoz-Gil	Poulsen-Nautrup	Cesa	
12:00 - 15:30	Lunch+Discussions							
15.30 - 16:30	Coffee + Snacks	arrival BUS						
16:30 - 17:05	Invited	arrvial BUS	Hammerer	Clerk	**FREE**	Kaiser	Zhang	
17:05 - 17:40	Invited/Hot topic	arrival BUS	Langen	Bernien	**FREE**	Buchhold	Shahmoon	
17:40 - 18:00	Hot topic	**Registration**	Guan	Bychek	**FREE**	Kollath	Kersten	
18:00 - 18:30	Discussions	**Registration**			**ascent to Hohe Mut**			
18:30 - 19:00		Dinner	Dinner	Dinner	**Conference Dinner**	Dinner	Dinner	
19:00 - 20:00		Dinner		Posters A-M	**at**	Posters N-Z		
20:00 - 22:00				Posters A-M	**Hohe Mut**	Posters N-Z		
22:00 - 22:30					**descent from Hohe Mut**			