BOOK OF ABSTRACTS

POSTER CONTRIBUTIONS

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1. ENTANGLEMENT OF TWO DISTANT TRANSMON QUBITS USING GAUSSIAN-CORRELATED BEAMS

ALEJANDRO ANDREAS JUANES I ISTA

We study the entanglement generation between two distant transmon qubits driven with the output fields of a non-degenerate parametric amplifier. The continuous Gaussian two-mode squeezed state produced by the amplifier will drive the two-qubit subsystem into a highly entangled steady state due to dissipation, despite the finite bandwidth of the squeezed states and the network losses. For it, we embed the qubits in two separate waveguides and couple them to superconducting resonators to do quantum tomography of the final state. The qubit is strongly coupled to the one-dimensional coplanar waveguide, showing a strong atom-field interaction on resonance. However, the coupling to a continuum of modes limits the lifetime of the qubit state, which will affect the fidelity of the single-shot readout. The ability to convert continuous- to discrete-variable entanglement will pave the way for robust operation of superconducting quantum networks.

2. ESTIMATING LOCAL OBSERVABLES WITH SNAPSHOTS OF LOCAL CLIFFORD UNITARIES

ANDREA CAPROTTI I UNIVIE

Verifying large quantum systems represents one of the main challenges for real applications. Methods such as full-state tomography require quantum resources that scale exponentially with the dimensions. However, often the goal is to access only particular information about the quantum state. New methods can significantly reduce the consumption of resources: a good example is the protocol of classical shadows, which utilises the outcomes of randomised Clifford measurements. This work aims to investigate only low-depth Clifford measurements to extract useful information about a quantum system. We obtain bounds for the number of copies required to obtain expectation values of local observables: for Pauli (binary) observables the sampling complexity scales as (2^l + 1)^N/l, which for l → N corresponds precisely to the bound obtained for global measurements. Our result shows that significant estimation accuracy can be achieved even with moderate resources and low-depth quantum circuits.

3. PROGRAMMABLE MULTI-PHOTON QUANTUM INTERFERENCE IN A SINGLE SPATIAL MODE

LORENZO CAROSINI I UNIVIE

The interference of non-classical states of light enables quantum-enhanced applications reaching from metrology to computation. Most commonly, the polarization or spatial location of single photons are used as addressable degrees of freedom for turning these applications into praxis. However, the scale-up for the processing of a large number of photons of such architectures is very resource demanding due to the rapidly increasing number of components, such as optical elements, photon sources and detectors. Here we demonstrate a resource-efficient architecture for multi-photon processing based on time-bin encoding in a single spatial mode. We employ an efficient quantum dot single photon source and a fast programmable time-bin interferometer, to observe the interference of up to 8 photons in 16 modes, all recorded only with one detector−−thus considerably reducing the physical overhead previously needed for achieving equivalent tasks. Our results can form the basis for a future universal photonics quantum processor operating in a single spatial mode.

4. GROUPING OF ENTANGLEMENT IN QUANTUM ANNEALING

MAIKE DRIEB-SCHÖN I UIBK

The behaviour of entanglement in quantum annealing processes is relatively little researched. In this paper, we point out a property of entanglement during an annealing process that has not yet been addressed. For both, the logical problem and its physical embedding named parity encoding, we study the behaviour of bipartite entanglement. The parity embedding maps arbitrary combinatorial optimization problems onto a 4-local Hamiltonian and is the generalization of the Lechner-Hauke-Zoller (LHZ) embedding. We observed a bundling of bipartite entanglement values for a low energy subspace which is separated from the rest of the energy spectrum by a finite spectral gapWe show a grouping of bipartite entanglement in the case of the parity encoding, which is induced by the embedding itself. Further, we demonstrate that the choice of the parity layout of the more general parity embedding has an influence on the entanglement values.

5. MULTIPLEXED COMMUNICATION IN QUANTUM NETWORKS

JULIA FREUND I UIBK

A great deal of past research on quantum communication protocols has focused on proving a single long-distance point-to-point or multiuser communication request at a time. With our research we consider the next step ahead, which is the development of protocols for multiple, multiplexed communication requests at the same time. We focus on entanglement-based quantum networks, which provide a multipartite-entangled resource state prior to the request. This resource state is manipulated dynamically by local operations and measurements together with classical communication on request without further demand in sending information via quantum channels. We present intermediate results towards simultaneous, bipartite communication requests in a multiplexed fashion, while enabling maximum flexibility on requests.

6. MULTI-TASK GENERATIVE DIFFUSION MODELS IN QUANTUM INFORMATION

FLORIAN FÜRRUTTER I UIBK

Generative models show astonishing results in visual and natural language domains. Prominent examples are diffusion models, able to produce high quality images from text descriptions. We use diffusion models as a multi-task generative tool in the domain of quantum information. First, we show the ability of the method to generate quantum circuits with different entanglement patterns, conditioned on input prompts stating the desired Schmidt-Rank-Vectors. Furthermore, we use the diffusion model as a quantum circuit compiler, i.e., we provide a unitary and a gate set and let the model produce the gate decomposition. Additionally, the latter allows optimizing and transpiling given circuits. Due to the nature of generative models, generating many circuits is cheap at inference. Generally, we find that the model produces a great variety of unique and new, not in the training-set, quantum circuits. Using this, the results can be used for discovering sub-arrangements or replacement rules.

7. NOISE CANCELING IN QUANTUM SENSOR NETWORKS

ARNE HAMANN I UIBK

We consider the sensing of commuting scalar-valued fields with specific spatial dependence using a network of qubit sensors, e.g. multiple atoms located at different positions within a trap. We show how to harness the spatial correlations to sense only a specific signal and be insensitive to others by constructing an (approximate) decoherence-free subspace. This maintains Heisenberg-scaling, despite the presence of multiple noise sources.

8. INDUCTIVELY SHUNTED TRANSMON (IST) QUBIT

FARID HASSANI BIJARBOONEH I ISTA

Currently available quantum processors are dominated by noise, which severely limits their applicability and motivates the search for new physical qubit encodings. In this work, we introduce the inductively shunted transmon, a weakly flux-tunable superconducting qubit that offers charge offset protection for all levels and a 20-fold reduction in flux dispersion compared to the state-of-the-art resulting in a constant coherence over a full flux quantum. The parabolic confinement provided by the inductive shunt as well as the linearity of the geometric superinductor facilitates a high-power readout that resolves quantum jumps with a fidelity and QND-ness of >90% and without the need for a Josephson parametric amplifier. Moreover, the device reveals quantum tunneling physics between the two prepared fluxon ground states with a measured average decay time of up to 3.5 h. In the future, fast time-domain control of the transition matrix elements could offer a new path forward to also achieve full qubit control in the decay-protected fluxon basis.

9. FLUXON PROTECTION IN INDUCTIVELY SHUNTED TRANSMON REGIME

LUCKY KAPOOR I ISTA

The inductively shunted transmon (IST) [1] is a qubit derived from the rf-SQUID circuit that has shown properties resembling the transmon while retaining flux tunability but without the charge dispersion. The IST qubit explores the regime of EJ/EC>>1 and EJ/EL>>1 which also exponentially suppresses fluxon transitions. The delocalization of the wave functions of the fluxon states lead to extremely long relaxation times in the order of few hours. Due to the low fluxon transition matrix, flux qubit encoding is challenging in the IST limit. By populating the cavity with a large number of photons, inter-well transitions can be performed via photon-assisted tunneling. It allows fluxon state preparation to further probe the tunneling mechanism in the IST qubit. In the future, fast time-domain control of the transition matrix elements could offer a new path forward to also achieve full qubit control in the decay-protected fluxon basis. This could be a promising route toward new decay-protected qubit encoding schemes suitable for dynamical decoupling techniques and biased noise error correction codes.

[1] Hassani, Farid, et al. Nature Communications 14.1 (2023): 3968.

10. QUANTUM SIMULATION WITH 2D CRYSTALS IN A NOVEL RF TRAP

DOMINIK KIESENHOFER I UIBK

Trapped ions in rf traps are a well-established platform for analog and variational quantum simulation of quantum many-body systems. Up to now, ions in linear Paul traps allow for experiments with up to 50 spins in a linear configuration including quantum control of individual qubits. In our project, we aim for extending this approach to the second dimension enabling studies of 2d spin models with a larger particle number. Using a novel micro-fabricated linear Paul trap, we are able to stably trap and ground-state cool 2d ion crystals of up to 105 ions laying the foundation for future quantum simulation experiments. Moreover, we successfully realize spin-spin interactions by coupling laser fields to the out-of-plane vibrational modes and assess these interactions using spin-squeezing experiments. In this poster, we give an overview of our experimental apparatus and the results achieved so far.

11. DETECTING QUANTUM COHERENCE AT A DISTANCE

DANIEL KUN I UNIVIE

In this work, we realise an operational procedure to distinguish a classical mixture from a quantum superposition through an XOR quantum communication game. The task is to determine the effect of an intervention made by a referee on two (superposed) paths without re-interfering them. In previous theoretical work, the referee was given beam blockers, resulting in a predicted probability to win (Pwin) of 9/16 for a quantum superposition, whilst for a classical mixture Pwin is 1/2. In this work, we show that by replacing the beam blockers with phase shifters, we can increase the predicted quantum Pwin to 3/4. We experimentally implement this task using photon pairs from a Spontaneous Parametric Down-Conversion (SPDC) source and achieve an experimental Pwin = 0.696 ± 0.009, well above the classical limit. Additionally, we contrast the quantum and classical cases by varying the mixedness of the source particle from a pure state to a fully mixed state and find strong agreement with the theoretical predictions. Finally, our work shows that this procedure not only allows us to observe the presence of a coherent superposition but also to extract the value of the relative phase between two paths without interfering them.

12. RECURSIVE GREEDY INITIALIZATION OF THE QUANTUM APPROXIMATE OPTIMIZATION ALGORITHM WITH GUARANTEED IMPROVEMENT

RAIMEL A. MEDINA RAMOS I ISTA

The quantum approximate optimization algorithm (QAOA) is a variational quantum algorithm, where a quantum computer implements a variational ansatz consisting of p layers of alternating unitary operators and a classical computer is used to optimize the variational parameters. For a random initialization, the optimization typically leads to local minima with poor performance, motivating the search for initialization strategies of QAOA variational parameters. Although numerous heuristic initializations exist, an analytical understanding and performance guarantees for large p remain evasive. We introduce a greedy initialization of QAOA which guarantees improving performance with an increasing number of layers. Our main result is an analytic construction of 2p+1 transition states - saddle points with a unique negative curvature direction - for QAOA with p+1 layers that use the local minimum of QAOA with p layers. Transition states connect to new local minima, which are guaranteed to lower the energy compared to the minimum found for p layers. We use the GREEDY procedure to navigate the exponentially increasing with p number of local minima resulting from the recursive application of our analytic construction. The performance of the GREEDY procedure matches available initialization strategies while providing a guarantee for the minimal energy to decrease with an increasing number of layers p.

13. INFLUENCE OF NOISE IN ENTANGLEMENT-BASED QUANTUM NETWORKS

MARIA FLORS MOR RUIZ I UIBK

We consider entanglement-based quantum networks as one of the key applications of upcoming quantum technologies. These architectures are based on establishing a resource state, which is a multipartite entangled state, between the nodes in the network. In particular, we focus on graph states as resources states. To this aim, we investigate the influence of noise on the manipulation of graph states and the required storage. Specifically, we study in detail the scenario where the target state is a Bell pair. We assume depolarizing noise to model the influence of decoherence (storage errors) and imperfect operations on graph states.

14. LOGICAL QUANTUM SYSTEMS FOR REMOTE CONTROL, QUANTUM SIMULATION & COMPUTATION

FERRAN RIERA SABAT I UIBK

We consider many-body systems of spatially distributed qubits with a distance-dependent two-body interaction. We group the qubits in sets, treating them collectively to encode logical systems. These logical systems behave like physical qubits where we can ture their interactions by properly choosing the logical subspace states. We introduce three applications of such systems. (1) One logical qubit can be used to control a target system of the same kind remotely. (2) A universal quantum simulator from several logical qubits can be constructed, providing advantages over standard simulators. (3) We can perform noise-resilient quantum computation in these logical systems. Finally, we bring all these elements together to build a modular entangled-based quantum computer.

15. CIRCUMVENTING SUPEREXPONENTIAL RUNTIMES FOR HARD INSTANCES OF QUANTUM ADIABATIC OPTIMIZATION

BENJAMIN SCHIFFER I MPQ

Classical optimization problems can be solved by adiabatically preparing the ground state of a quantum Hamiltonian that encodes the problem. The performance of this approach is determined by the smallest gap encountered during the evolution. Here, we consider the maximum independent set problem, which can be efficiently encoded in the Hamiltonian describing a Rydberg atom array. We present a general construction of instances of the problem for which the minimum gap decays superexponentially with system size, implying a superexponentially large time to solution via adiabatic evolution. The small gap arises from locally independent choices, which cause the system to initially evolve and localize into a configuration far from the solution in terms of Hamming distance. We investigate remedies to this problem. Specifically, we show that quantum quenches in these models can exhibit signatures of quantum many-body scars, which in turn, can circumvent the superexponential gaps. By quenching from a suboptimal configuration, states with a larger ground state overlap can be prepared, illustrating the utility of quantum quenches as an algorithmic tool.

16. APPROACHING THE THERMODYNAMIC LIMIT OF A FIRST-ORDER DISSIPATIVE QUANTUM PHASE TRANSITION IN ZERO DIMENSION

RIYA SETT I ISTA

The photon blockade breakdown process has been predicted to be an example of the first order dissipative phase transition (DPT) in a driven-dissipative Jaynes-Cummings model. In this work, we study the DPT in a finite-size cQED system consisting of one superconducting qubit and a single cavity mode in presence of a strong resonant drive. We show the key feature of such a DPT – coexistence of two macroscopically distinct states – dim and bright states – with the observable bistable signal. We also approach the regime of “thermodynamic limit”, where both the timescale and the amplitude of the observable approach infinity, resulting in long-lived and macroscopically distinct dim and bright phases. Moreover, we show experimental phase diagram in the drive detuning-drive strength plane for the first time in this particular situation.

17. AUTOMATED GADGET DISCOVERY IN THE QUANTUM DOMAIN

LEA TRENKWALDER I UIBK

Reinforcement Learning (RL) has demonstrated remarkable success in its application to quantum physics and, more broadly, scientific discovery. Due to the growing complexity of the problems addressed by RL, interpreting its solutions becomes ever more challenging. In this work, we propose a post-hoc analysis method using sequence mining and clustering to gain insights into an RL agent's behavior. By distilling frequent and compact subroutines as gadgets and by grouping them according to diverse metrics, we uncover how the agent solves a given task. Our three-stage approach involves data generation with an RL agent, extraction of gadgets using a mining algorithm, and organization of gadgets via a density-based clustering algorithm. We apply this method to two quantum-inspired RL environments, where gadgets represent compact experimental setups, like interferometers, or useful subroutines of quantum protocols, like teleportation.

18. OPTIMAL CIRCUITS FOR THE OBSERVATION OF DUAL SHAPIRO STEPS IN A SINGLE JOSEPHSON JUNCTION

ANDREA TRIONI I ISTA

Mesoscopic Josephson junctions (JJs) exhibit complex behavior arising from the interplay between charge and phase. At low temperatures, they transition between inductive superconducting behavior with well-defined phase (EJ >> EC) and capacitive insulating behavior with localized charge (EC >> EJ). In a DC-biased IV curve, the former results in phase-coherent Cooper pair current flow (supercurrent), while the latter shows Coulomb blockade effects. When irradiated with an external microwave (f), superconducting JJs display constant-voltage Shapiro steps (Vn = n Φ0 f) due to phase locking. Quantum Phase Slip junctions (QPSJ), approximated by insulating JJs, exhibit dual Shapiro steps in current (In = n (2e) f), observed in recent experiments. We present our numerical and experimental progress to achieve these effects in a single JJ in a high-impedance electromagnetic environment. Understanding the superconducting to insulator quantum phase transition (SIT) in Josephson junction circuits remains a challenge with potential applications in protected superconducting qubits and quantum metrology.

19. ERROR MITIGATION FOR QANTUM APPROXIMATE OPTIMIZATION

ANITA WEIDINGER I UIBK

Solving optimization problems on near term quantum devices requires developing error mitigation techniques to cope with hardware decoherence and dephasing processes. We propose a mitigation technique based on parity encoding. This method uses a redundant encoding of logical variables to solve optimization problems on fully programmable planar quantum chips. We discuss how this redundancy can be exploited to mitigate errors in quantum optimization algorithms. In the specific context of the quantum approximate optimization algorithm (QAOA), we show that errors can be significantly mitigated by appropriately modifying the objective cost function.

20. NETWORK OF TRAPPED-ION QUANTUM PROCESSORS

MOMING JIA I UIBK

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