Q 44: Quantum Networks (joint session QI/Q)

Time: Wednesday 14:30–16:45 Location: HS VIII

Invited Talk Q 44.1 Wed 14:30 HS VIII

Generating entangled states in quantum networks — •Nikolai Wyderka[1], Justus Neumann[1], Tulja Varun Kondra[1], Kiara Hansenne[2], Lisa T. Weinbrenner[2], Hermann Kampermann[1], Otfried Gühne[2], and Dagmar Bruss[1] — [1]Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf, Germany — [2]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, 57068 Siegen, Germany

Which states can be generated in quantum networks? We investigate this question in n-partite quantum networks connected by bipartite sources, assuming local operations and shared randomness (LOSR). We show that for many target states, the question can be reduced to the tripartite network scenario.

Consequently, we show that for the class of multipartite graph states, the reducibility is connected to the task of Greenberger-Horne-Zeilinger (GHZ) state extraction. Here, one asks whether n parties that share a graph state and are distributed into three groups can create a GHZ state shared between them using only group-local unitary operations. We show that for each connected graph state, it is always possible to find a tripartition that yields at least one GHZ state.

Finally, we exploit our findings to derive fidelity bounds on states preparable in LOSR networks with any graph state by deriving strong fidelity bounds in tripartite quantum networks.

Q 44.2 Wed 15:00 HS VIII

Designing a Microwave-to-Optical Transducer based on a High-Overtone Bulk Acoustic-Wave Resonator — •Tom Schatteburg[1,2], Maxwell Drimmer[1,2], Rodrigo Benevides[1,2], Samuel Pautrel[1,2], Hugo Doeleman[1,2], Benjamin Neubauer[1,2], Luca Ben Herrmann[1,2], and Yiwen Chu[1,2] — [1]Department of Physics, ETH Zürich, Zurich, Switzerland — [2]Quantum Center, ETH Zürich, Zürich, Switzerland

Microwave to optical transducers convert quantum states from platforms such as superconducting circuits into the thermal noise-free optical regime, promising a route towards a quantum network using telecom fibers as links. A widespread approach is to use a mechanical resonator as intermediate system that couples to both microwaves and optical photons. High-overtone bulk acoustic-wave resonators (HBARs) are a platform for which both electromechanical and optomechanical strong coupling as well as optomechanical ground state operation has been demonstrated. Here we present the design and intermediate results of building a microwave to optical transducer which uses an HBAR as intermediary. We demonstrate the insensitivity to laser light absorption of the acoustic mode as key advantage of the HBAR, and outline the path to combining microwave, acoustics and optics into one system. We discuss overcoming the challenges that arise when building the transducer, such as making high-frequency superconducting qubits, multimode dynamics, cryogenic alignment, and developing new materials.

Q 44.3 Wed 15:15 HS VIII

Hollow-core light cage waveguides for atomic vapor quantum memories — •Esteban Gómez-López[1], Dominik Ritter[1], Jisoo Kim[2], Harald Kübler[3], Markus Schmidt[2,4], and Oliver Benson[1] — [1]Humboldt-Universität zu Berlin, 12489, Berlin, Germany — [2]Leibniz Institute of Photonic Technology, 07745, Jena, Germany — [3]Universität Stuttgart, 70550, Stuttgart, Germany — [4]Otto Schott Institute of Material Research, 07743, Jena, Germany

Quantum memories play a fundamental role in synchronizing quantum network nodes. Using electromagnetically induced transparency (EIT) in hot atomic vapors provides easy-to-handle systems capable of storing light for up to seconds [1] and at the single photon level [2]. Recently we have shown that a novel photonic structure, a nanoprinted hollow-core light cage (LC), can enhance the effects of EIT when interfaced with Cs vapor, with the advantage of faster diffusion of atoms inside the core compared to other hollow-core structures [3]. In this work, we show the storage of faint coherent light pulses in the atomic medium confined within the core of the LC for hundreds of nanoseconds. The intrinsic efficiency of the memory was optimized by performing a parameter scan on the signal bandwidth and control power driving the memory. This paves the way towards an on-chip integrated module for quantum memories and as a platform for coherent interaction of light and warm atomic vapors. [1] Katz, O. and Firstenberg, O., Nat. Commun. 9, 2074 (2018). [2] Wolters, J., et al., Phys. Rev. Lett. 119(6), 060502 (2017). [3] Davidson-Marquis, F., et al., Light. Sci. Appl. 10, 114 (2021).

Q 44.4 Wed 15:30 HS VIII

Entanglement purification in multipartite quantum router setups with multiplexing — •Julia Alina Kunzelmann, Hermann Kampermann, and Dagmar Bruss — Heinrich Heine University Düsseldorf

Quantum routers are essential for transmitting quantum information over long distances in quantum networks. To enhance the entanglement distribution rate memory multiplexing can be used. However, quantum memories will decohere, which we compensate by entanglement purification. Our work presents an extended protocol that includes both multiplexing and entanglement purification. For entanglement purification, we use the protocol from Deutsch et al. (1996), which we apply pairwise to the quantum memories before performing GHZ measurements. Depolarized qubits in the quantum memories can be replaced or purified by new arriving qubits with higher fidelities. We analyze the fidelity of the distributed GHZ states under various network conditions. Further, we discuss different purification strategies based on our numerical simulations.

Q 44.5 Wed 15:45 HS VIII

Graph states fidelity bound in networks with local operation and shared randomness — •Justus Neumann[1], Tulja Varun Kondra[1], Nikolai Wyderka[1], Kiara Hansenne[2], Lisa Weinbrenner[2], Hermann Kampermann[1], Otfried Gühne[2], and Dagmar Bruss[1] — [1]Heinrich-Heine-Uinversität Düsseldorf — [2]Universität Siegen

We analyze quantum networks of spatially separated parties, where some parties are connected by quantum channels (links), enabling the distribution of pairwise entangled states. Additionally, each party has access to a shared classical random variable. Quantum states generated under these conditions are referred to as LOSR states (Local Operations and Shared Randomness). Characterizing this class of network states is often challenging, as determining whether a given state can be realized within a given network configuration is non-trivial. We derive an analytical upper bound on the fidelity of the set of LOSR states with any connected graph state, with particular emphasis on the GHZ state.

Q 44.6 Wed 16:00 HS VIII

Genuine networks bounds on distillable GHZ and conference key in pair-entangled networks — •Anton Trushechkin, Hermann Kampermann, and Dagmar Bruss — Heinrich Heine University Düsseldorf, Faculty of Mathematics and Natural Sciences, Institute for Theoretical Physics III, Universitätsstr. 1, Düsseldorf 40225

A fundamental problem of the bipartite entanglement theory is the derivation of upper bounds on distillable entanglement (EPR pairs) and distillable secret key if a source of bipartite (entangled) states is given and LOCC (local operations and classical communication) or LOPC (local operations and public communication) maps are allowed. The same fundamental problems arises in the network scenario. We consider networks where nodes are connected with bipartite entangled sources.

Obviously, GHZ or conference key distillation is not easier than EPR or bipartite secret key distillation between two subsets of nodes constituting an arbitrary bipartition of nodes. Thus, we can apply known bipartite bounds. The existing network bounds are based on this idea of bipartition.

In the present talk, we propose genuine network bounds on distillable GHZ and conference key in pair-entangled networks, i.e. which are not reduced to bipartitions of nodes. To do this, we introduce suitable LOCC and LOPC monotones originating from putting together ideas from classical and quantum information theory and graph theory.

Q 44.7 Wed 16:15 HS VIII

Collective quantum phases emerging in superconducting qubits networks — •Benedikt J.P. Pernack, Mikhail V.

Fistul, and Ilya M. Eremin — Theoretische Physik III, Ruhr-Universität Bochum, Bochum 44801, Germany

We present a theoretical study of collective quantum phases occurring in exemplary vertex-sharing superconducting qubits networks, i.e., frustrated sawtooth chains of Josephson junctions embedded in a dissipationless transmission line. The building block of such networks is a triangular superconducting cell containing two 0-Josephson junctions and one π-Josephson junction. In the frustrated regime, the low-energy quantum dynamics of a single cell is governed by the presence of persistent currents flowing (anti)clockwise corresponding to (anti)vortex configurations. The direct embedding of π-Josephson junctions to the transmission line results in short- or long-range interactions between vortices and antivortices of different cells. Employing a variational approach the quantum dynamics of such qubits networks was mapped to an effective XX spin model where the exchange interaction between spins decays with distance as $x^{-\beta}$, and the local terms represent the coherent quantum superposition of vortex-antivortex pairs [1]. Combining exact numerical diagonalization and quasi-classical mean field approach, we identified various collective quantum phases such as the paramagnetic (P), compressible superfluid (CS) and weakly compressible superfluid (w-CS) states.

[1] B.J.P. Pernack, M.V. Fistul, I.M.Eremin, Phys. Rev. B 110, 184502 (2024).

Q 44.8 Wed 16:30 HS VIII

Towards a Suburban Quantum Network Link — •Pooja Malik[1,2], Florian Fertig[1,2], Yiru Zhou[1,2], Tommy Block[1,2], Maya Bueki[3], Tobias Frank[3], Gianvito Chiarella[3], Marvin Scholz[3], Pau Ferrera[3], Gerhard Rempe[3], and Harald Weinfurter[1,2,3] — [1]Fakultät für Physik, Ludwig- Maximilians-Universität, Munich, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany — [3]Max-Planck Institut für Quantenoptik, Garching, Germany

Distributed quantum computing, quantum sensing and secure quantum communication are all much anticipated applications of quantum networks. The primary blocks of these networks are quantum nodes and the foremost task is to distribute entanglement between distant quantum nodes. Here we present a quantum node based on a single Rb87 atom capable of distributing entanglement between a single atom and a single photon over a 23 km deployed telecom fiber. To achieve transfer in commercial fiber network the single photons are converted to telecom wavelength to evade high attenuation loss at 780 nm. With active polarization compensation over the deployed fiber and long atomic coherence time of 7 ms [1] we measure atom-photon entanglement fidelity of more than 80%. This is a crucial step to realize a city-to-city scale quantum network link when, in the future, connecting to another Rb87 atom node at the remote end of fiber link [2]. [1] Y. Zhou et al., PRX Quantum 5, 020307, 2024 [2] M. Brekenfeld et al., Nature Physics 16, 647-651 (2020)