FM 37: Open and Complex Quantum Systems II

Time: Tuesday 14:00–16:00 Location: 3042

FM 37.1 Tue 14:00 3042

Gauge optimization in locally purifying tensor network states — •Lennart Bittel[1], Albert H. Werner[2], and Martin Kliesch[1] — [1]Heinrich Heine University Düsseldorf, Germany — [2]University of Copenhagen, Denmark

We have developed cost effective methods for finding good unitary gauges for locally purified tensor network quantum states. Tensor network methods have proven to be a useful tool to simulate interacting quantum systems. Such methods have also been extended from closed to open quantum systems. By relying on so-called *local purifications* positivity issues can be avoided and trace norm error control can be provided. However, purifications of quantum states have a unitary gauge freedom on the purifying system. This gauge freedom is shared by locally purified states and can practically lead to significant errors and large bond dimensions. In this work, we develop gauge optimization algorithms based on conjugate gradient methods and a version of adaptive linear regression. We demonstrate that this gauge optimization can be applied locally in order to significantly reduce the bond dimensions and to improve the accuracy of algorithms relying on local purifications with a small overhead.

FM 37.2 Tue 14:15 3042

Dissipation-assisted matrix product factorization — •Alejandro D. Somoza, Oliver Marty, James Lim, Susana F. Huelga, and Martin B. Plenio — Institut für Theoretische Physik and IQST, Universität Ulm, Ulm, Germany

Charge and energy transfer in biological and synthetic organic materials are strongly influenced by the coupling of electronic states to a highly structured dissipative environment. Non-perturbative simulations of these systems require a substantial computational effort and current methods can only be applied to large systems if environmental structures are severely coarse-grained. Time evolution methods based on tensor networks are fundamentally limited by the times that can be reached due to the buildup of entanglement in time, which quickly increases the size of the tensor representation, i.e., the bond dimension. In this work, we introduce a dissipation-assisted matrix product factorization (DAMPF) method that combines a tensor network representation of the vibronic state within a pseudomode description of the environment where a continuous bosonic environment is mapped into a few harmonic oscillators under Lindblad damping. This framework is particularly suitable for a tensor network representation, since damping suppresses the entanglement growth among oscillators and significantly reduces the bond dimension required to achieve a desired accuracy. We show that dissipation removes the *time-wall* limitation of existing methods, enabling the long-time simulation of large vibronic systems consisting of 10-50 sites coupled to 100-1000 underdamped modes in total and for a wide range of parameter regimes.

FM 37.3 Tue 14:30 3042

Design principles for long-range energy transfer at room temperature — •Andrea Mattioni, Felipe Caycedo-Soler, Susana Huelga, and Martin Plenio — Ulm University, Ulm, Germany

Typical room temperature conditions hinder ballistic long-range transfer of excitations, and are hence considered to prevent quantum phenomena to serve as tools for the design of efficient and controllable energy transfer over significant time and length scales. However, it is well-known that relevant dynamical properties of many-body systems depend on the quantum properties of minimal repeating units and, as we show here, excitonic energy transfer is no exception. With the support of an exactly solvable model, we are able to show how exciton delocalization and the ensuing formation of dark states within unit cells can be harnessed to support classical propagation over macroscopic distances. We specifically discuss the role of such factors in nanofabricated arrays of bacterial photosynthetic complexes via extensive simulations. This allows us to resolve the until now unexplained experimental observation of exciton diffusion lengths in such arrays in terms of an interplay between intra-unit cell thermalization and delocalization, which cooperate to create and use robust dark states at room temperature. Based on these factors, we provide quantum design guidelines at the molecular scale to optimize both energy transfer speed and diffusion range over macroscopic distances in artificial light-harvesting architectures.

FM 37.4 Tue 14:45 3042

Wave-particle duality of many-body quantum states — •Christoph Dittel[1,2], Gabriel Dufour[2,3], Gregor Weihs[1], and Andreas Buchleitner[2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria — [2]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany — [3]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität-Freiburg, Albertstr. 19, 79104 Freiburg, Germany

We formulate a quantitative theory of wave-particle duality for many-body quantum states and derive complementarity relations for the wave and particle character of many identical bosons or fermions equipped with a tunable level of distinguishability. We show that our complementarity relations fundamentally constrain measurement statistics and interference visibilities in general experimental settings with possibly interacting particles, and, thereby, provide a versatile framework to certify and benchmark complementarity and particle indistinguishability in many-body quantum protocols.

FM 37.5 Tue 15:00 3042

Eigenstate Complexity of Interacting Bosons on a Lattice — •Lukas Pausch, Alberto Rodríguez, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

Multifractality has proven to be an efficient quantifier of the complexity of many-particle states in Fock space, and it has been used to expose ground state phase transitions [1,2]. In our present numerical study, we use multifractality to investigate Fock space complexity for the full set of eigenstates of the Bose-Hubbard Hamiltonian. We examine the evolution of the distribution of generalized fractal dimensions as a function of interaction strength and in relation to the behaviour of the energy spectrum. This analysis reveals that the eigenstate structure in Hilbert space changes drastically across the energy canvas for different values of the interaction. Furthermore, we investigate possible connections between multifractality and the emergence of quantum chaos.

[1] J. Lindinger, A. Buchleitner and A. Rodríguez, Phys. Rev. Lett. 122, 106603 (2019).

[2] D. J. Luitz, F. Alet and N. Laflorencie, Phys. Rev. Lett. 112, 057203 (2014).

FM 37.6 Tue 15:15 3042

Quantum walks of two cobosons — •mama kabir njoya mforifoum[1], gabriel dufour[1,2], and andreas buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Germany — [2]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität Freiburg, Germany

A quantum walker is a particle evolving coherently over a network of sites, and therefore has the ability to interfere with itself, contrary to its classical counterpart. The extension to many-particle quantum walks, together with non-vanishing particle-particle interactions, leads to many-particle interference phenomena which are controlled by the particles' statistics (bosonic or fermionic), their degree of mutual distinguishability, and the interaction strength. We focus on the scenario of two interacting co-bosons (pairs of bound fermions) on a 1D lattice, systematically explore characteristic dynamical features as determined by the location in parameter space, and discriminate the observed behaviour against that of two elementary bosons.

FM 37.7 Tue 15:30 3042

Observation and stabilization of photonic Fock states in a hot radio-frequency resonator — Mario F. Gely[1], •Christian Dickel[3,1], Marios Kounalakis[1], Jacob Dalle[1], Remy Vatre[1], Brian Baker[2], Mark D. Jenkins[1], and Gary A. Steele[1] — [1]Kavli Institut of Nanoscience, Delft University of Technology, The Netherlands — [2]Department of Physics and Astronomy, Northwestern University, United States of America — [3]Institute of Physics II, University of Cologne, Germany

In quantum mechanics, the ultimate limit of a weak field is a single-photon. Detecting and manipulating single photons at megahertz frequencies presents a challenge because thermal fluctuations are significant, even at millikelvin temperatures. Here, we use a superconducting transmon qubit to directly observe photon-number splitting of the transition frequency due to a megahertz electrical resonator. Using the qubit, we achieve quantum control over thermal photons, sideband cooling the system and stabilizing photonic Fock states. Releasing the resonator from our control, we directly observe its re-thermalization with nanosecond resolution. Extending circuit quantum electrodynamics to a new regime, we enable the exploration of thermodynamics with photon-number resolution and allow interfacing quantum circuits with megahertz systems, for example, electro-mechanical oscillators.

FM 37.8 Tue 15:45 3042

Discrete quantum time crystal signature of nuclear spins coupled to nitrogen-vacancy centers in diamond — •Jianpei Geng — 3rd Institute of Physics, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

In view of spacetime invariance, it is quite natural to consider about the concept of time crystal in analogy to crystal. A time crystal is expected to show periodic pattern in time and to break time translation symmetry. Although a quantum time crystal of a static equilibrium system has been ruled out, discrete quantum time crystal can exist for periodically driven systems. The discrete quantum time crystal signature has been observed in several systems such as trapped ions, ensemble nitrogen-vacancy centers, and nuclear spins in NMR samples. However, an insight what interaction of the system would lead to the time crystal signature is still lacking. Here, we broaden the insight by showing that nuclear spins with negligible coupling between each other can still exhibit discrete quantum time crystal signature. The time crystal signature is stimulated by the coupling between the nuclear spins and a nitrogen-vacancy center or coupled nitrogen-vacancy centers.