FM 66: Poster: Entanglement

Time: Wednesday 16:30–18:30 Location: Tents

FM 66.1 Wed 16:30 Tents

Macroscopic boundary effects in the one-dimensional extended Bose-Hubbard model — •Sebastian Stumper, Junichi Okamoto, and Michael Thoss — University of Freiburg, Germany

The one-dimensional extended Bose Hubbard model shows various quantum phases due to its competing interactions. For large on-site interactions, a Mott insulating (MI) phase exists, while a charge density wave (CDW) phase becomes dominant for large nearest-neighbour interactions. In between these phases a topologically non-trivial phase of a Haldane insulator (HI) appears [Phys. Rev. Lett. 97, 260401 (2006)]. Ground state properties and low energy spectra are, however, very sensitive to the treatment of boundary conditions [arXiv:1403.2315 (2014)].

We study an open chain of the extended Bose Hubbard model with different edge potentials using the density matrix renormalization group method based on matrix product states [Comput. Phys. Commun. 225, 59 (2018)]. Without edge potentials, the CDW and HI phases exhibit a non-degenerate ground state, and the order parameters change signs in the middle of the chain. This feature is robust against finite size scaling and is explained by a simple effective picture for the low energy states. On the other hand, with large edge potentials, the sign change of the order parameters disappears, and we recover uniform bulk ground states. The effect of the boundary conditions on the entanglement spectrum is also investigated.

Furthermore, we elaborate on the quench dynamics and discuss the results in terms of our findings on the equilibrium phases.

FM 66.2 Wed 16:30 Tents

Robustness of Topological Order in Toric Code in various setups — •Amit Jamadagni Gangapuram and Hendrik Weimer — Institut für Theoretische Physik, Leibniz Universität Hannover, Hannover, Germany.

We analyze the robustness of topological order in the toric code in various setups with open boundaries. We probe for the presence of a possible phase transition in (a) closed systems in the presence of external perturbation (b) interpolating different topological phases both in closed and open setups. For the latter, we show that interpolating the underlying topology as well as interpolating between different boundaries induces a phase transition in closed systems and we further extend this to study similar behavior in open systems by engineering effective dissipative collapse operators. To detect the phase transition we compute different numerical signatures like the Ground State Degeneracy (GSD), Topological Entanglement Entropy (TEE), Minimally Entangled States (MES), the expectation of the loop operator among others. The open boundary conditions introduce cases with non-degenerate ground states leading to an interesting analysis of topological order, both in open and closed systems.

FM 66.3 Wed 16:30 Tents

Dynamical driving a Cavity-BEC System from self-organized into non equilibrium — •Christoph Georges[1], Hans Kessler[1], Jayson G. Cosme[1,2], Ludwig Mathey[1,2], and Andreas Hemmerich[1,2] — [1]Institut für Laser-Physik and Zentrum für Optische Quantentechnologien, Universität Hamburg, D-22761 Hamburg, Germany — [2]The Hamburg Center of Ultrafast Imaging, Luruper Chaussee 149, D-22761 Hamburg, Germany

The generation and manipulation of density wave order in many body systems are considered as models for solid-state phenomena such as light-induced superconductivity.

In our recent research, we investigated the role of modulation on the formation of long-range order in a Cavity-Atom System. For this, a Bose-Einstein Condensate of Rubidium Atoms is placed inside the light field of a high finesse cavity. By pumping the atoms with a sufficient strong transversal optical standing wave, the system can go through a phase transition. The arising phase is characterized by an intracavity light field due to the formation of particle density waves [1].

By modulating the amplitude of pump field, the DW-order can either be suppressed [2] or new DW-orders can be excited [3]. In the present work, we modulated the light field with a frequency close to a collective resonance. We observe the excitation of a higher DW-order and the rise of a subradiant non-equilibrium phase.

[1] J. Klinder et. al. PNAS 112, 3290 (2015)
[2] Ch. Georges et. al. PRL 121, 220405 (2018)
[3] J. G. Cosme et. al. PRL 121, 153001 (2018)

FM 66.4 Wed 16:30 Tents

Initial-state dependence of the long-time dynamics in a spin-boson system — •Sebastian Wenderoth and Michael Thoss — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany

Thermalization of a system refers to the process of approaching a unique steady state that depends only on a few macroscopic observables. Triggered by the development of new experimental tools, the question how an isolated quantum system can equilibrate to such a state under its own dynamics has recently received renewed interest. Various numerical studies suggest that subsystems of isolated quantum systems can equilibrate under unitary time evolution. This relaxation is caused by the remainder of the system acting as an effective bath. However, as the hybridization between the subsystem and the remainder increases this simple picture breaks down and the influence of the remainder on the subsystem can change qualitatively.

Inspired by a recent experiment with trapped-ions [1], we investigate a special type of a spin-boson model. Employing the multilayer multiconfiguration time dependent Hartree method [2], we simulate the dynamics of the system in a numerically exact way. As a function of the spin-boson coupling, we observe a qualitative change of the dynamics of the spin, induced by the coupling to the bosonic modes, ranging from the usual relaxation dynamics for small couplings to non-stationary long-time states of the spin that depend on its initial state.

[1] G.Glos *et al.*, Phys. Rev. Lett. **117**, 170401 (2016)
[2] H. Wang *et al.*, J. Chem. Phys. **119**, 1289 (2003)

FM 66.5 Wed 16:30 Tents

Optimal Control of Schrödinger cat states of increasing size — •Matthias G. Krauss and Christiane P. Koch — Theoretische Physik III - Universität Kassel, D-34132 Kassel, Germany

"Schrödinger cat states" are non-classical superposition states that are useful in quantum information science, for example for computing or sensing. Optimal control theory provides a powerful tool for preparing these superposition states, for example in experiments with superconducting qubits [Ofek et al., Nature 536, 441445 (2016)]. The optimized control fields and the resulting dynamics are typically rather complex and an in depth analysis of dynamics is often omitted. Our goal is to analyze the underlying control mechanisms for Schrödinger cat state preparation and understand the physical strategies found by the algorithm. In particular, our objective is the generation of different cat states in a Bose-Hubbard model with increasing particle number. We use Krotovs method [Reich et al., J. Chem. Phys. 136, 104103 (2012)] to generate the different cat states, analyze the dynamics induced by the optimized fields and investigate whether the control mechanism varies as the particle number is increased.

FM 66.6 Wed 16:30 Tents

Non-equilibrium states of two coupled oscillators and entanglement spectra — •Carsten Henkel — University of Potsdam, Institute of Physics and Astronomy, Germany

We study models of coupled quantum systems that are driven out of (local) equilibrium by coupling to different heat baths [1–6]. Two coupled oscillators, each embedded in its "own" bath of oscillators, provide a simple, analytically solvable system. We study fluctuation-dissipation relations and correlation functions (covariance matrices) beyond the Markov and rotating-wave approximations. Deviations from local equilibrium provide a characterisation in the frequency domain of the entanglement between the two oscillators [2]. Interesting generalisations may involve coupled spins or spin baths. Relevant applications are heat transport [1,4–6] and single molecular emitters coupled to nano-antennas [7].

[1] A. Pérez-Madrid, J. M. Rubí, and L. C. Lapas, Phys. Rev. B 77 (2008) 155417
[2] Anne Ghesquière, Ilya Sinayskiy, and Francesco Petruccione, Phys. Scr. 2012 (2012) 014017
[3] I. Dorofeyev, Can. J. Phys. 91 (2013) 537
[4] Svend-Age Biehs and Girish S. Agarwal, J. Opt. Soc. Am. B 30 (2013) 700

[5] Gabriel Barton, J. Phys. Condens. Matt. 27 (2015) 214005
[6] Gabriel Barton, J. Stat. Phys. 165 (2016) 1153
[7] Ruben Esteban, Javier Aizpurua, and Garnett W Bryant, New J. Phys. 16 (2014) 013052

FM 66.7 Wed 16:30 Tents

Entanglement between Yu-Shiba-Rusinov states in STM devices — •Ciprian Padurariu[1], Haonan Huang[2], Simon Dambach[1], Björn Kubala[1], Christian Ast[2], and Joachim Ankerhold[1] — [1]Institute for Complex Quantum Systems and IQST, Ulm University, 89069 Ulm, Germany — [2]Max-Planck-Institut für Festkörperforschung, 70569 Stuttgart, Germany

We study the theory and experimental realization of tunneling between tip and substrate Shiba states in superconducting STM devices operating at 15 mK. We show that the elementary transport process involves splitting a Cooper pair, thereby entangling the spin of quasiparticles localized in the subgap states.

Our simple analytical results are in good agreement with conductance measurements exhibiting peaks in the tunnel current at a number of sub-gap bias voltages. [1] The voltages are identified as resonances of sub-gap discrete magnetic states, so called Shiba states, that form inside a volume around the magnetic impurity of coherence length size. [2]

The tunnel current between Shiba states gives rise to new resonances. These narrow current peaks are a result of the interplay between spin-entangled quasiparticle pairs and slow decoherence processes arising due to quasiparticle poisoning.

[1] M. Ruby, F. Pientka, Y. Peng, F. von Oppen, B. W. Heinrich, and K. J. Franke, Phys. Rev. Lett. 115, 087001 (2015).
[2] M. I. Salkola, A. V. Balatsky, and J. R. Schrieffer, Phys. Rev. B 55, 12648 (1997).

FM 66.8 Wed 16:30 Tents

Entangled optical clock states in ^{40}Ca^{+} — •Ludwig Krinner[1], Kai Dietze[1], Lennart Pelzer[1], Stephan Hannig[1], Nicolas Spethmann[1], and Piet O. Schmidt[1,2] — [1]QUEST Institute for Experimental Quantum Metrology, Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Leibniz Universität Hannover, 30167 Hannover, Germany

Single ion optical clocks are limited in their statistical uncertainty by quantum projection noise. Increasing the number of ions while maintaining low systematic uncertainties is demanding. In such a situation, entangling atoms on an optical transition can improve the statistical uncertainty. Furthermore, using especially engineered quantum states, the transition can be made free of the linear Zeeman shift. We present in this poster progress towards preparing a pair of ^{40}Ca^{+} ions in a decoherence free entangled subspace, which is both robust against magnetic field fluctuations and allows shorter interrogation times for a given stability (compared to two uncorrelated ions). We present first results on a successful implementation of Mølmer Sørensen entangling gates and discuss possible avenues of reaching the decoherence free subspace.