Q 20: Quantum Many-Body Dynamics

Time: Tuesday 11:00–13:00 Location: HS 3118

Q 20.1 Tue 11:00 HS 3118

Loss-tolerant photonic fusion networks for quantum computing with quantum emitters — •Matthias C. Löbl, Stefano Paesani, and Anders S. Sørensen — Center for Hybrid Quantum Networks (Hy-Q), The Niels Bohr Institute, University of Copenhagen, Blegdamsvej 17, DK-2100 Copenhagen, Denmark

Graph states are entangled states that enable measurement-based quantum computing, an approach that is particularly promising for architectures using photons as qubits. However, generating the required large photonic graph states is complicated by photon losses and the fact that photon-photon gates are difficult to realize. To generate large graph states, we consider an approach that connects small graph resource states by probabilistic entangling gates (Bell measurements called fusions). To make the scheme practical, we use resource states that are locally equivalent to GHZ states and readily can be generated using quantum emitters. Furthermore, we consider fusion networks where all fusions are performed at once which is advantageous as it minimizes the required adaptiveness and the need for long memory time. We optimize the tolerance to photon loss of several such schemes where either purely photonic graph states or spin-photon entangled states are used. The latter approach is particularly suited for quantum emitters with a spin degree of freedom and we find a tolerance to photon loss of more than 6% for such architectures [1]. Finally, we also discuss algorithms to simulate the photon loss threshold as a non-standard percolation model.

[1] Matthias C. Löbl et a., arxiv:2304.03796 (2023)

Q 20.2 Tue 11:15 HS 3118

Quantum stochastic resetting in lattices with long-range hopping — •Sayan Roy[1], Shamik Gupta[2], and Giovanna Morigi[1] — [1]Theoretical Physics, Department of Physics, Saarland University, 66123 Saarbrücken, Germany — [2]Department of Theoretical Physics, Tata Institute of Fundamental Research, 1 Homi Bhabha Road, Mumbai, 400005, India

Stochastic resetting [1] is considered an efficient strategy for spatial search. The corresponding quantum dynamics is a lively area of research [2]. In this work, we analyze the dynamics of a quantum particle on a one-dimensional lattice with long-range hopping. The hopping decays with the distance as $1/r^{\alpha}$. The particle is additionally subject to repeated projective measurements by a detector placed at the target site and, in case of negative result, it is reset with constant rate to the initial site. We determine the hitting time of the target as a function of α and find the optimal resetting rate required to maximize the detection probability. We further consider the effect of box disorder on the hopping rate and assess the speed of the convergence time as a function of the disorder strength.

[1]. M.R. Evans and S.N. Majumdar, Phys. Rev. Lett. 106, 160601 (2011). [2]. R. Yin, E. Barkai, Phys. Rev. Lett. 130, 050802 (2023).

Q 20.3 Tue 11:30 HS 3118

Topological Quantum Optics in Atomic Emitter Arrays — •Jonathan Sturm and Adriana Pálffy — Julius-Maximilians-Universität Würzburg

Quantum emitter arrays are a powerful platform enabling tailored control of quantum optical phenomena, like super- and subradiance or efficient photon storage [1]. Since state-of-the-art experimental techniques allow the realization of almost arbitrary lattice structures, a natural question is what physical effects arise if the lattice has non-trivial topology.

Here, we study a one-dimensional chain of quantum emitters implementing the Su-Schrieffer-Heeger model. Going beyond previous studies [2], we show how the presence or absence of topologically protected edge states depends on the orientation of the transition dipole moment with respect to the chain axis. Moreover, we discuss how the deliberate breaking of inversion and sublattice symmetry gives rise to non-Hermitian topological states and the emergence of the non-Hermitian skin effect [3]. Our results demonstrate the potential of atomic emitter arrays as a platform for topological quantum optics.

[1] M. Reitz *et al.*, PRX Quantum **3**, 010201 (2022).
[2] B. X. Wang and C. Y. Zhao, Phys. Rev. A **98**, 023808 (2018).
[3] E. J. Bergholtz *et al.*, Rev. Mod. Phys. **93**, 015005 (2021).

Q 20.4 Tue 11:45 HS 3118

Exploring the phase structure of the three-flavor Schwinger model in the presence of a chemical potential with measurement- and gate-based quantum computing — •Stephan Schuster[1], Stefan Kühn[2], Lena Funcke[3], Tobias Hartung[4], Marc-Oliver Pleinert[1], Joachim von Zanthier[1], and Karl Jansen[2] — [1]Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 1, 91058 Erlangen, Germany — [2]CQTA, Deutsches Elektronen-Synchrotron DESY, Platanenallee 6, 15738 Zeuthen, Germany — [3]Transdisciplinary Research Area "Building Blocks of Matter and Fundamental Interactions" (TRA Matter), University of Bonn, Bonn, Germany — [4]Northeastern University - London, Devon House, St Katharine Docks, London, E1W 1LP, United Kingdom

We propose an variational quantum eigensolver (VQE) ansatz, allowing us to explore the phase structure of the multi-flavor Schwinger model in the presence of a chemical potential. The ansatz can incorporate relevant model symmetries via constrains on the variational parameters, and can be implemented on circuit-based as well as measurement-based quantum devices. Classical simulations of the VQE show that our ansatz captures the phase structure of the model, and can approximate the ground state to a high level of accuracy. Moreover, proof-of-principle simulations on a superconducting, gate-based quantum hardware allow to determine the critical points in the considered region of the phase diagram with very good precision.

Q 20.5 Tue 12:00 HS 3118

Quantum state preparation via engineered ancilla resetting — Daniel Alcalde Puente[1], Felix Motzoi[1], Tommaso Calarco[1,2,3], Giovanna Morigi[4], and •Matteo Rizzi[1,2] — [1]Institute of Quantum Control, Peter Grünberg Institut (PGI-8) - Forschungszentrum Julich GmbH, Jülich, Germany — [2]Institute for Theoretical Physics - University of Cologne, Köln, Germany — [3]Dipartimento di Fisica e Astronomia - Universita di Bologna, Bologna, Italy — [4]Theoretical Physics - Saarland University, Saarbrucken, Germany

In this study, we investigate a quantum resetting protocol for preparing ground states of frustration-free Hamiltonians. The protocol uses a steering Hamiltonian for local coupling to ancillary degrees of freedom, which are periodically reset. For short reset times, the dynamics resemble a Lindbladian with the target state as its steady state. We use Matrix Product State simulations and quantum trajectory methods to assess the protocol's efficiency in preparing the spin-1 Affleck-Kennedy-Lieb-Tasaki state, focusing on convergence time, fidelity, and energy evolution at various reset intervals. Our findings indicate that entanglement with the ancillary system is crucial for rapid convergence, with an optimal reset time for peak performance. The protocol also demonstrates robustness against small deviations in reset time and dephasing noise. Our results suggest that quantum resetting could be more advantageous than other methods like quantum reservoir engineering in certain contexts.

Q 20.6 Tue 12:15 HS 3118

Decoding the projective transverse field Ising model — •Felix Roser, Hans Peter Büchler, and Nicolai Lang — Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, University of Stuttgart, 70550 Stuttgart, Germany

The competition between non-commuting projective measurements in discrete quantum circuits can give rise to entanglement transitions. It separates a regime where initially stored quantum information survives the time evolution from a regime where the measurements destroy the quantum information. Here we study one such system - the projective transverse field Ising model - with focus on its capabilities as a quantum error correction code. The idea is to interpret one type of measurements as errors and the other type as syndrome measurements. We demonstrate that there is a finite threshold below which quantum information encoded in an initially entangled state can be retrieved reliably. In particular, we implement the maximum likelihood decoder to demonstrate that the error correction threshold is distinct from the entanglement transition. This implies that there is a finite regime where quantum information is protected by the projective dynamics, but cannot be retrieved by using syndrome measurements.

Q 20.7 Tue 12:30 HS 3118

Antiferromagnetic bosonic t-J models and their quantum simulation —

•Timothy J. Harris[1,2], Ulrich Schollwöck[1,2], Annabelle Bohrdt[2,3], and Fabian Grusdt[1,2] — [1]Department of Physics and Arnold Sommerfeld Center for Theoretical Physics (ASC), Ludwig-Maximilians-Universität München, 80333 München, München, Germany — [2]Munich Center for Quantum Science and Technology, 80799 München, Germany — [3]Institut für Theoretische Physik, Universität Regensburg, 93035 Regensburg, Germany

Understanding the microscopic origins of the competition between spin and charge degrees of freedom is a central challenge at the heart of strongly correlated many-body physics. Recently, the combination of optical tweezer arrays with systems exhibiting strong interactions, such as Rydberg atoms or ultracold polar molecules, has opened the door for quantum simulation platforms to explore a wide variety of spin models. A significant next step will be the combination of such settings with mobile dopants, in order to study the physics of doped quantum magnets. Here we present recent numerical results from large-scale density matrix renormalization group (DMRG) calculations investigating the phase diagram of the bosonic t-J model with cylindrical boundary conditions at low doping. By introducing antiferromagnetic (AFM) couplings between neighbouring spins, we realize competition between the charge motion and magnetic order similar to that observed in high-Tc cuprates.

Q 20.8 Tue 12:45 HS 3118

Non-Hermitian study of driven-dissipative topological semimetals —

•Daniel Borrero Landazabal[1,2], Flore K. Kunst[2], and Sharareh Sayyad[2] — [1]Institute of Quantum Technologies, German Aerospace Center (DLR), Wilhem-Runge-Str. 10, 89081 Ulm, Germany — [2]Max Planck Institute for the Science of Light, Staudtstraße 2, 91058 Erlangen, Germany.

One of the intriguing lines of research in recent years in quantum physics is probing, manipulating, and optimizing topological phases under the influence of ultrafast laser pulses. While in most cases the topological systems are theoretically treated as closed systems, explaining and interpreting some of recent experimental observations were not viable without incorporating the formulation of open quantum systems. Of particular interest is understanding 3D Weyl and Dirac semimetals, like the TaAs, as well as chiral topological semimetals like the RhSi, due to their particularities in electron transport phenomena. In this project, we investigate such systems in a driven-dissipative configuration. To achieve this, we employed various techniques from open quantum systems and non-Hermitian physics. Using these methods, we could evaluate the dynamics of the density matrix, explore its relaxation dynamics, and characterize the topological nature of the system with nonzero dissipation. In particular, we explored the low-energy $(\mathbf{k} \cdot \mathbf{p})$ models of the TaAs and the RhSi compounds and implemented an effective non-Hermitian model. A key result is the discovery of exceptional points (EPs) of high order in the complex spectrum of the two compounds.