FM 42: Poster: Quantum Computation

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

FM 42.1 Tue 16:30 Tents

A generalized search algorithm for quantum reinforcement learning — •Sabine Wölk, Arne Hamann, and Hans J. Briegel — Institut für Theoretische Physik, Universität Innsbruck, 6020 Innsbruck, Austria

Grover's search is a well-known example of a quantum algorithm that provides a computational speedup with respect to the best classical counterpart. Among its several applications, Grover's search has been used also in quantum machine learning and specifically to speed up algorithms for reinforcement learning. However, the search space in reinforcement learning tasks is not necessarily static, that is, the length of a single entry, as well as the number of entries and the target space are flexible. This represents a critical issue for the exploration stage during learning. Here, we propose a generalization of Grover's search algorithm to monotonically increasing search spaces that is beneficial to tackle this issue in quantum reinforcement learning.

FM 42.2 Tue 16:30 Tents

Quantum Approximate Optimization for Industry Use Cases — •David Headley[1,2] and Frank Wilhelm-Mauch[2] — [1]Daimler AG, Stuttgart, Germany — [2]Universität des Saarlandes, Saarbrücken, Germany

The Quantum Approximate Optimization Algorithm (QAOA) is one of several quantum algorithms that may be capable of outperforming classical algorithms using a quantum computer without full quantum error correction. In this work, we explore the applicability of QAOA to use cases from industry. We consider techniques to pre-satisfy constraints and mix within constraint-satisfying sub-spaces and show how some problems can be pre-compiled to smaller, maximally hard subproblems. Methods such as these will allow quantum computers that are small, noisy, and connectivity-limited to provide greatest performance.

FM 42.3 Tue 16:30 Tents

Neural Decoders for the Toric Code — •Thomas Wagner, Hermann Kampermann, and Dagmar Bruss — Heinrich-Heine-Universität Düsseldorf, Institute for Theoretical Physics 3

Surface codes are a promising method of quantum error correction. However, their efficient decoding is still a problem. Recently, approaches based on machine learning techniques have been proposed by Torlai and Melko, as well as Varsamopoulos et al. A significant problem is that these methods require large amounts of training data even for relatively small code distances. The above-mentioned methods were tested on the rotated surface code which encodes one qubit. Here, we show they are viable even for the toric surface code which encodes two qubits. Furthermore, we explain how symmetries of the toric code can be exploited to reduce the amount of training data that is required to obtain good decoding results.

FM 42.4 Tue 16:30 Tents

Performance of trapped-ion based quantum error correction under crosstalk noise. — •Pedro Parrado Rodriguez, Ciaran Ryan-Anderson, and Markus Muller — Swansea University,Singleton Park, Swansea SA2 8PP, United Kingdom

Protecting quantum information from errors is essential for large-scale quantum computation. In this work, we study the performance of a distance-3 color code in a trapped ions setup, with particular focus on the effects of crosstalk errors and the different ways to suppress them.

FM 42.5 Tue 16:30 Tents

Neural Network Decoders for Topological Codes — •Kai Meinerz and Simon Trebst — Institute for Theoretical Physics, Cologne

Currently, topological error correction codes, especially the surface code, are the most achievable roadmap for large-scale fault-tolerant quantum computation. For the realization it is of importance to obtain fast and flexible decoding algorithms for these codes. Using neural networks, it is possible to learn the possibility distribution of errors in an error correcting code and in addition, these distributions can be traced back to the syndrome of the corresponding errors. We present various implementations of such an algorithm that can be applied to any stabilizer code. We demonstrate the decoders on the well-known two dimensional toric code.

FM 42.6 Tue 16:30 Tents

Gaussian Sums on the IBM Q Experience — •Alexander Wolf[1] and Wolfgang Schleich[1,2] — [1]Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany — [2]Institute for Quantum Science and Engineering (IQSE), Department of Physics and Astronomy, Texas A&M University, College Station, TX 77843, USA

Using the IBM Quantum Experience we investigate two qubits implementing a state which resembles a special case of a Gaussian sum. That state is a superposition of the four two-qubits basis states with phases rising quadratically in the summation index. Hence, measuring this state in the superposition basis yields the modulus squared of the sum hidden within the statistics of multiple runs. We construct an explicit gate sequence and run it for different time parameters that determine the phases. Subsequently a one-parameter Kraus decomposition is used to explain the difference between results of the quantum and classical calculation.

FM 42.7 Tue 16:30 Tents

Neural Networks for Reconstructing Quantum Gas Microscope Images — •Bastian Lunow, Niklas Käming, Andreas Kerkmann, Michael Hagemann, Mathis Fischer, Klaus Sengstock, and Christof Weitenberg — ILP Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Quantum gas microscopes allow to image single atoms in optical lattices and therefore give a new window into many-body physics with microscopic access. One challenge is to reconstruct the occupation of the atoms on the lattice from finite fluorescence signal, even when the lattice sites are not fully optically resolved by the imaging system. Reconstruction algorithms allow to reconstruct them anyway. It has already been shown that this can be done with conventional methods, but we hope to achieve better results by using neural nets which are known to be efficient in extracting features from image data. Here we investigate the use of machine learning techniques in order to improve upon the conventional reconstruction algorithms with the promise to yield a faithful and faster reconstruction already for lower fluorescence counts. Using the concrete example of a triangular pinning lattice, we focus on realistic parameters for lithium atoms. Fruitful architectures include variational autoencoders and the use of weight initializations. These approaches would open a path to applying quantum gas microscopes to more general setup and more exotic atomic species.

FM 42.8 Tue 16:30 Tents

Investigating ultracold interactions between Ba^+ ions and Li atoms — •Pascal Weckesser, Fabian Thielemann, Daniel Hoenig, Isabelle Lindemann, Florian Hasse, Leon Karpa, and Tobias Schaetz — Physikalisches Institut, Albert-Ludwigs-Universitaet, Germany

The interplay of ultracold atoms and ions has recently gained interest [1], due to its wide applications in quantum simulations of solid state systems [2] as well as in quantum computing [3]. In order to implement a reliable atom-ion platform, it is necessary to prepare the mixture at ultracold temperatures. Optical trapping of ions [4] provides a new pathway to achieve these ultracold atom-ion mixtures, as it overcomes the intrinsic micromotion heating effects of a conventional Paul trap [5].

In this poster we present our experimental hybrid-setup combining individual $^{138}Ba^+$ ions in a linear Paul trap with ^6Li atoms in a crossed optical dipole trap. First reaction measurements between the two constituents will be shown. We further analyse elastic collisions leading to possible cooling within the Paul trap and discuss its current limitations. In the future we want to overcome these limitations by confining both species in a combined optical dipole trap.

[1] A. Haerter et al., Cont. Phys., Vol. 55, issue 1, pages 33-45 .
[2] U. Bissbort et al., Phys.Rev.Lett. 111.8 (2013): 080501.
[3] Doerk et al., Phys. Rev. A 81.1 (2010): 012708.
[4] T. Schaetz, Journal of Physics B: 50.10 (2017): 102001.
[5] M.Cetina et al., Phys.Rev.Lett. 109,253201 (2012)

FM 42.9 Tue 16:30 Tents

Rapid counter-diabatic and inhomogeneous sweeps in lattice gauge adiabatic quantum computing — •Andreas Hartmann[1] and Wolfgang Lechner[2] — [1]Institute for Theoretical, University of Innsbruck, A-6020, Austria — [2]Institute for Theoretical, University of Innsbruck, A-6020, Austria

We present a coherent counter-diabatic quantum protocol to prepare ground states in the lattice gauge mapping of all-to-all Ising models (LHZ) with considerably enhanced final ground state fidelity compared to a quantum annealing protocol. We make use of a variational method to find approximate counter-diabatic Hamiltonians that has recently been introduced by Sels and Polkovnikov [Proc. Natl. Acad. Sci. 114, 3909 (2017)]. The resulting additional terms in our protocol are time-dependent local on-site y-magnetic fields. A single free parameter is introduced which is optimized via classical updates. The protocol consists only of local and nearest-neighbor terms which makes it attractive for implementations in near term experiments.

We further present an inhomogeneous driving protocol in LHZ with modified transverse fields with improved ground state fidelity and enlarged minimal energy gaps. The inhomogeneously driven transverse field introduces an additional time-dependent parameter that improves the efficiency of the method. For the 2D lattice gauge model LHZ we analytically derive the free energy term and numerically verify it.

FM 42.10 Tue 16:30 Tents

Wigner Crystals in Two-Dimensional Materials as a Platform for Quantum Simulation — •Johannes Knörzer[1], Martin J. A. Schuetz[2], Geza Giedke[3,4], Richard Schmidt[1], Dominik S. Wild[1], Kristiaan de Greeve[2], Mikhail D. Lukin[2], and J. Ignacio Cirac[1] — [1]Max-Planck-Institut f. Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]Physics Department, Harvard University, Cambridge, MA 02318, USA — [3]Donostia International Physics Center, Paseo Manuel de Lardizabal 4, E-20018 San Sebastian, Spain — [4]Ikerbasque Foundation for Science, Maria Diaz de Haro 3, E-48013 Bilbao, Spain

We analyze and characterize Wigner crystals in two-dimensional semiconductors and highlight their suitability as a platform for quantum information processing. Self-assembled crystals constitute a rich playground of quantum many-body physics. In particular, Wigner crystals are prime candidates for the realization of regular electron lattices with minimal requirements on external control and electronics. In agreement with previous works, we find that transition metal dichalcogenides (TMDs) offer an ideal platform for the observation of quantum Wigner crystals, even at finite temperature and residual disorder. Here we demonstrate how these systems can be used to investigate interacting spin networks. Owing to their unique electronic and optical properties, we find that those semiconductors may allow for an an all-optical non-destructive read-out of Wigner crystals.

FM 42.11 Tue 16:30 Tents

Superfluid phases of long-range interacting bosons — •Rebecca Kraus[1], Shraddha Sharma[1], Krzysztof Biedroń[2], Jakub Zakrzewski[2], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, Saarbrücken, Germany — [2]Instytut Fizyki imienia Mariana Smoluchowskiego, Uniwersytet Jagielloński, Kraków, Poland

The quantum statistical mechanics of long-range interacting systems is to large extent unexplored. The simulation in the laboratory using cold atom systems would allow one to test predictions and gain understanding on a problem, which is often intractable numerically. In this work we theoretically analyse the interplay of long-and short-range interactions on the onset of superfluidity in a gas of bosons in an optical lattice. We first show that long-range interactions give rise to additional hopping terms which depend nonlineary on the onsite density, and which have different forms depending on the range of the interactions. We then focus on van-der-Waals and on dipolar interactions in a quasi one dimensional geometry. In this regime superfluid phases have been predicted, which have different properties as a function of the density and of the strength of the interactions. We characterize their stability and properties by means of DMRG numerical simulations. We then compare our predictions to the mean-field predictions of the superfluid phases of all-connected atoms, as for ultracold atoms in optical resonators. Our study is performed using experimental accessible parameters, our predictions can be verified in existing experimental setups.

FM 42.12 Tue 16:30 Tents

Interplay between phase transitions and excitation dynamics in Coulomb crystals — •Lars Timm[1], Tanja E. Mehlstäubler[2], Luis Santos[1], and Hendrik Weimer[1] — [1]Institute for theoretical physics, Leibniz University, Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

In the last decade the field of energy transport and thermodynamics in low-dimensional systems regained interest. Main motivation for these studies is the question which essential processes lead to the phenomenologically established Fourier's law.

Therefore, simple low-dimensional lattice models with various interactions and external potentials have been developed. Heat transport turned out to be not trivial at all in these systems. Diverging thermal conductivity and the lack of temperature gradients pose clear contrasts to Fourier's law.

An excellent system to study thermodynamics, in arbitrary dimensions in the classical as well as in the quantum regime, are trapped ions. In addition to the precise control of the particles in ion traps, Coulomb crystals captivate due to the possibility of solitonic defects (kinks) with additional dynamics and symmetry broken phases.

In this work, we investigate how energy transport takes place in different phases of a Coulomb crystal. The dynamics of a local excitation in the crystal and the transport properties of kinks are analyzed. The results hint towards interesting thermodynamical phenomena of ion crystals with defects.

FM 42.13 Tue 16:30 Tents

A multi-site quantum register of neutral atoms — •Malte Schlosser, Daniel Ohl de Mello, Dominik Schäffner, Tilman Preuschoff, Lars Kohfahl, Jan Werkmann, Lukas Brozio, and Gerhard Birkl — Institut für Angewandte Physik, TU Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany

Advanced quantum technologies, such as quantum simulation, computation, and metrology are thriving for the implementation of large-scale configurations of identical quantum systems. Sets of atoms and molecules have the advantage of having identical intrinsic properties but need to be placed in identical environments as well. We introduce a unique micro-optical platform of arrays of optical tweezers and demonstrate the compensation of the differential Stark shift caused by the optical trapping potential. This results in a strong suppression of dephasing effects and a significant increase of the coherence time for atomic ensembles of ^{85}Rb. The experimental method does not require the existence of a so called magic wavelength and is expandable to other atomic species trapped in various dipole trap configurations of arbitrary wavelength.

Furthermore, we implement Rydberg interacting systems in defect-free 2D clusters of individual atoms and discuss recent work with microlens arrays fabricated by femtosecond direct laser writing, which enables the on-demand production of highly adaptable geometries for neutral-atom based quantum engineering [2].

[1] M. Schlosser et. al., arXiv:1902.00370 (2019).
[2] D. Schäffner et. al., arXiv:1905.06929 (2019).