Q 35: Quantum Computing and Simulation IV

Time: Wednesday 14:30–16:30 Location: P 10

Invited Talk Q 35.1 Wed 14:30 P 10

Quantum field simulation on bosonic platforms — •Tobias Haas — Institut für Theoretische Physik and IQST, Universität Ulm, Albert-Einstein-Allee 11, 89069 Ulm, Germany — Centre for Quantum Information and Communication, École polytechnique de Bruxelles, CP 165, Université libre de Bruxelles, 1050 Brussels, Belgium

Quantum field simulators offer unique opportunities to investigate otherwise inaccessible phenomena through tabletop experiments. Taming the complexity of such inherently high-dimensional models requires efficient encodings paired with experimentally friendly readout methods.

First, we introduce the Optical Time Algorithm (OTA) as a unifying framework that enables the simulation of a wide range of free quantum field dynamics using a single optical circuit design [1]. By modifying the optical elements' parameters, our method allows us to engineer essentially arbitrary timescales, coupling graphs, spacetime metrics, and boundary conditions.

Second, we put forward the classical entropy method as a universal data-driven toolkit for directly probing information measures from typical measurement data [2]. We show that well-known features of quantum information measures carry over to suitably chosen classical measures. As applications, we demonstrate the area-to-volume law transition in the quench dynamics of a spin-1 Bose-Einstein condensate [3,4] and report the first experimental observation of an area law in an interacting quantum field simulator [5].

[1] arXiv:2506.23838 [2] arXiv:2404.12320 [3] PRAL 112, L011303 [4] NJP 27, 043004 [5] arXiv:2510.13783

Q 35.2 Wed 15:00 P 10

Shortcuts to adiabaticity with a quantum control field — •Emma King[1], Giovanna Morigi[1,2], and Raphaël Menu[1,3] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Center for Quantum Technologies (QuTe), Saarland University, Campus, 66123 Saarbruecken, Germany — [3]CESQ/ISIS (UMR 7006), CNRS and Université de Strasbourg, 67000 Strasbourg, France

Quantum adiabatic dynamics underpins adiabatic quantum computing and quantum annealing. Shortcuts to adiabatic dynamics traditionally use engineered classical drives to suppress non-adiabatic transitions and accelerate protocols. Here we study quantum state transfer in the Landau-Zener model as a minimal setting that captures the essentials of adiabatic evolution, and show that undesired (non-adiabatic) transitions can instead be suppressed by autonomous quantum control. This involves coupling the Landau-Zener qubit to an auxiliary quantum system. By tuning the frequency and interaction strength we modify the joint spectrum and composite quantum dynamics such that the probability of non-adiabatic transitions is reduced by more than two orders of magnitude in favorable regimes. We further identify a practical trade-off: relaxed requirements on the final time precision can be compensated by a longer evolution window. Importantly, the suppression of non-adiabatic transitions also persists in the presence of weak decoherence. Our results provide a clear example where the quantum nature of the control subsystem implements an effective shortcut to adiabaticity without relying on externally engineered classical fields.

Q 35.3 Wed 15:15 P 10

Bosonic QEC: (Squeezed) Cats and Vacua — •Florian Spiess — University of Mainz

Bosonic codes offer a promising route towards resource efficient and scalable quantum error correcting architectures, creating a pathway for fault tolerant quantum computation. An interesting feature and difficulty of some experimentally relevant codes, such as (squeezed) cat-codes, is their approximate nature, meaning they only fulfill the Knill-Laflamme conditions in certain limits of physical parameters.

In this talk we investigate the performance and benefits of squeezed vacuum, fock and cat codes. For the most dominant physical error process in photonic systems, that is photon loss, we analyze how to quantify if such newer encodings, involving squeezing, can help compared to other known bosonic error correcting schemes.

Q 35.4 Wed 15:30 P 10

Enhanced loading of ^{171}Yb in optical tweezer arrays for Quantum Computing — •Clara Schellong[1], Jonas Rauchfuss[1], Till Schacht[1], Ben Michaelis[1], Paul Callsen[1], Tobias Petersen[1], Nejira Pintul[1], Christoph Becker[1,2], and Klaus Sengstock[1,2] — [1]Center of Optical Quantum Technologies University of Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Institute for Quantum Physics University of Hamburg, Luruper Chaussee 149, 22761 Hamburg

Neutral atoms in optical tweezer arrays emerge as one of the most promising platforms for quantum computing, simulation, and metrology. In this talk, we present our experimental progress towards a quantum computing and simulation platform using Ytterbium (Yb) as a qubit resource, focusing on the deterministic loading of single atoms. In our experiment, we trap individual ^{171}Yb atoms in an array of tweezers at 759 nm, that is magic not only for the clock states $^1S_0$ and $^3P_0$ but also for the $^3P_1$, m_F =-1/2 state, relevant for cooling and detection. A key step for this platform is the defect-free preparation of these arrays. It is well known that light pulses blue-detuned to the $^1S_0$ - $^3P_1$ transition can induce light-assisted collisions that allow for enhanced loading probabilities of single atoms into tweezers. In our setup, we observe single-atom loading with over 80% efficiency using pulses red-detuned to the cooling transition. We characterize the influence of experimental parameters, like tweezer depth and magnetic field, identifying optimal conditions for frequencies red-detuned to the AC Stark and Zeeman shifted resonance of the F=3/2, m_F=-1/2 state.

Q 35.5 Wed 15:45 P 10

Development of a Cryogenic Ytterbium Tweezer Array and Modulation Transfer Spectroscopy of the $^1S_0 \to {}^3P_1$ Transition — •Julian Feiler[1,2], Meng Gu[3], Konrad Koenigsmann[3], Jin Yang[3], Max Hachmann[1,2], and Peter Schauss[1,2,3] — [1]Institute for Quantum Physics, University of Hamburg, Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany — [3]Department of Physics, University of Virginia, Charlottesville, USA

Alkaline-earth-like atoms are a common choice for ultracold neutral atom quantum simulators as well as universal quantum computers. Due to its nuclear spin of 1/2, fermionic ^{171}Yb incorporates a natural two-level system with a very long lifetime, which can be utilized as a qubit.

The objective of the presented experiment is the development of a cryogenic Yb tweezer array for quantum computing. In practice, the assembly of large arrays is limited by the trapping lifetime of the atoms in the optical tweezers. By using a cryogenic shield, collision rates of trapped atoms with background gas atoms can be decreased by several orders of magnitude. Correspondingly, the lifetime of the Yb atoms should increase from minute-scales up to many hours.

We report on the recent progress of the experiment and show data derived from modulation transfer spectroscopy of the $^1S_0 \to {}^3P_1$ transition of Yb in a vapor cell. The Zeeman splitting of ^{171}Yb and ^{173}Yb is also studied and shows significant deviations from linear Zeeman effect calculations at intermediate magnetic fields of less than 60 G.

Q 35.6 Wed 16:00 P 10

A neutral atom array in an optical cavity for quantum computing — •Mehmet Öncü[1,2,3], Balázs Dura-Kovács[1,2,3], Jacopo de Santis[1,2,3], Mullai Sampangi[1,2,4], Dimitrios Vasileiadis[1,2,3,4], Adrien Bouscal[1,2,3], and Johannes Zeiher[1,2,3] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), 80799 München, Germany — [3]Ludwig-Maximilians-Universität, Fakultät für Physik, Schellingstr. 4, 80799 München, Germany — [4]Technische Universität München, Fakultät für Physik, James-Franck-Str. 1, 85748 Garching, Germany

Neutral atoms in optical tweezer arrays have become a leading platform for quantum simulation, metrology, and computation. We leverage these developments to realize a novel experiment that strongly couples a rubidium atom array to a high-finesse optical resonator. We will present our compact and versatile setup, our ability to trap and manipulate individual rubidium atoms in optical tweezers inside the resonator, and the first measurements of their coupling to the cavity mode and coherent excitation to high-lying Rydberg states. This platform enables fast, high-fidelity control and readout, and opens routes toward cyclic error correction with real-time feedback, remote entan-

glement generation within and between atom arrays, and the quantum simulation of open system dynamics.

Q 35.7 Wed 16:15 P 10

Photonic simulation of quantum field dynamics — •Mauro D'Achille[1], Martin Gärttner[1], and Tobias Haas[2] — [1]FSU Jena — [2]Universität Ulm

Photonic multimode systems are an emerging quantum simulation platform ideally suited for emulating non-equilibrium problems in quantum field theory. I will present a new algorithm to decompose the time evolution operator generated by a large class of field-theoretic quadratic Hamiltonians in terms of optical elements. The peculiarity of this decomposition consists of the way in which the time parameter is taken into account. Indeed, for such a class, it is always possible to decouple the time evolution in time-dependent phase shifters by means of a proper time-independent symplectic transformation, composed by squeezers and beam splitters. I will conclude by presenting physically relevant examples and applications aimed to analyze and simulate how the information measures associated to local and non-local theories spread over time.