SYRY 3: Rydberg Physics in Single-Atom Trap Arrays 2

Time: Wednesday 14:00–16:00 Location: Audimax

SYRY 3.1 Wed 14:00 Audimax

Optimal quantum gates for a Rydberg atoms quantum computer — •Alice Pagano[1,2,3], Sebastian Weber[1], Hans Peter Büchler[1], and Simone Montangero[2,3] — [1]Institute for Theoretical Physics III, University of Stuttgart, Stuttgart, Germany — [2]Institute for complex quantum systems, University of Ulm, Ulm, Germany — [3]Dipartimento di Fisica e Astronomia "G. Galilei", Università di Padova, I-35131 Padova, Italy

Arrays of neutral atoms trapped in optical tweezers are a promising candidate for use in quantum computing. These platforms are highly scalable to large numbers of qubits and neutral atoms boost several attractive features as long coherence times and entanglement via strong dipole-dipole interactions by driving them to highly excited Rydberg states. We aim to realize a Rydberg atom quantum processor with several hundred qubits in the next few years. The smallest building blocks are one and two-qubit quantum gates: to entangle two atoms in the quantum register, a controlled-phase (CZ) gate will be implemented by shining laser pulses onto the two selected atoms. We exploit the Hamiltonian of two atoms to perform a numerical simulation that reproduces the behavior of the CZ gate. We take into account finite temperature, an imperfect Rydberg blockade, and decay out of the Rydberg state as well as a realistic finite raise time for the laser pulses. We compare a protocol with constant pulses obtained via classical optimizers against time-dependent pulses found through the optimal control algorithm dCRAB in an open-loop optimization. The optimal control solution improves the fidelity from 98.65% to 99.90%.

SYRY 3.2 Wed 14:15 Audimax

Time-Optimal Parallel Multiqubit Gates for Rydberg Atoms — •Sven Jandura and Guido Pupillo — Institute de Science et d'Ingénierie Supramoléculaires (ISIS), University of Strasbourg, 67000 Strasbourg, France

Entangling gates between two or more qubits stored in the electronic states of neutral atoms can be implemented via the strong and long-range interaction of atoms in highly excited Rydberg states. Two properties of a gate are particularly desirable: Firstly, the gate should be fast, since many types of error can be mitigated by short gate durations. Secondly, the gate should be parallel, meaning that only global instead of single site addressability with a control laser is needed, thereby simplifying the experimental setup. In this work we use two quantum optimal control techniques, gradient ascent pulse engineering (GRAPE) and Pontryagins's maximum principle, to determine time-optimal parallel laser pulses implementing a controlled-Z(CZ) gate and a three qubit C_2Z gate. Our pulses improve upon the traditional non-parallel pulses for the CZ and the C_2Z gate with just a limited set of variational parameters, demonstrating the potential of quantum optimal control techniques for advancing quantum computing with Rydberg atoms.

Invited Talk SYRY 3.3 Wed 14:30 Audimax

New frontiers in quantum simulation and computation with neutral atom arrays — •Giulia Semeghini — Harvard University

Learning how to create, study, and manipulate highly entangled states of matter is key to understanding exotic phenomena in condensed matter and high energy physics, as well as to the development of useful quantum computers. In this talk, I will discuss recent experiments where we demonstrated the realization of a quantum spin liquid phase using Rydberg atoms on frustrated lattices and a new architecture based on the coherent transport of entangled atoms through a 2D array. Combining these results with novel technical tools on atom array platforms could open a broad range of possibilities for the exploration of entangled matter, with powerful applications in quantum simulation and information.

Invited Talk SYRY 3.4 Wed 15:00 Audimax

New frontiers in atom arrays using alkaline-earth atoms — •Adam Kaufman — JILA/University of Colorado Boulder, Boulder, USA

Quantum science with neutral atoms has seen great advances in the past two decades. Many of these advances follow from the development of new techniques for cooling, trapping, and controlling atomic samples. As one example, the technique of optical tweezer trapping of neutral atom arrays has been a powerful tool for quantum simulation and quantum information, because it enables scalable control and detection of individual atoms with switchable interactions. In this talk, I will describe ongoing work at JILA where we have explored a new type of atom - two-electron atoms - for optical tweezer trapping. While their increased complexity leads to challenges, these atoms also offer new scientific opportunities by virtue of their rich internal degrees of freedom. Accordingly, they have impacted multiple areas in quantum science, ranging from quantum information processing to quantum metrology. I will report on my group's progress in these areas.

Invited Talk SYRY 3.5 Wed 15:30 Audimax

Spin squeezing with finite range spin-exchange interactions — •Ana Maria Rey — JILA, NIST and University of Colorado at Boulder

Squeezed states represent one class of entangled states which are important in quantum sensing and metrology. Typically, squeezed states are be realized via collective all-to-all interactions. However, in many quantum systems the only accessible interactions have a finite range, prohibiting the realization of such collective models. In this talk I will report how the XXZ spin model with interactions that fall off with distance r as $1/r^\alpha$ in D=2 and 3 spatial dimensions or XX spin models with soft-core interactions can realize spin squeezing comparable to the infinite-range $\alpha = 0$ model in a broad range of parameter regimes. In particular, I will discuss the application of these ideas to the case of weakly-dressed Rydberg atoms where an external drive can be used to engineer XX soft-core interactions and in turn to generate large levels of spin squeezing even in the presence of experimentally unavoidable decoherence sources.