Q 65: Poster – Ultra-cold plasmas and Rydberg systems (joint session A/Q)

Time: Thursday 17:00–19:00 Location: Philo 1. OG

Q 65.1 Thu 17:00 Philo 1. OG

Cryogenic Strontium Quantum Processor — •Roberto Franco, Xintong Su, Valerio Amico, Jonas Drotleff, and Christian Gross — University of Tübingen

In our project we aim at the unification of the optical tweezer technology with cryogenic technology at 4K, exploiting the stability of nuclear spin qubits encoded in fermionic strontium. This will result in record-long coherence and lifetimes of the atoms in the optical tweezer array. We report our efforts on the architecture to perform single qubit gates and the plans for adding two-qubit gates in the experiment.

Q 65.2 Thu 17:00 Philo 1. OG

Hilbert space fragmentation in driven-dephasing Rydberg atom array — •tianyi yan, chunhei leung, and weibin li — School of Physics and Astronomy and Centre for the Mathematics and Theoretical Physics of Quantum Non-equilibrium Systems, University of Nottingham, Nottingham NG7 2RD, United Kingdom

We investigate the onset and mechanism of Hilbert space fragmentation (HSF) in a chain of strongly interacting Rydberg atoms subject to local dephasing. It is found that the emergence of multiple long-lived metastable states is fundamentally tied to HSF of the driven-dephasing Rydberg atom system. We demonstrate that the manifesting HSF is captured by a dephasing PXP model that supports multiple degenerate zero modes. These modes form disconnected, block-diagonal subspaces of maximally mixed states, which consist of many-body spin states sharing the same symmetry. A key result is the identification of the underlying symmetry in the HSF, where conserved quantities in each subspace are defined by the consecutive double excitation addressing operator. Moreover, we show explicitly that the number of the fragmented Hilbert space grows exponentially with the chain length, following a modified Fibonacci sequence. Our work provides insights into many-body dynamics under dynamical constraints and opens avenues for controlling and manipulating HSF in Rydberg atom systems.

Q 65.3 Thu 17:00 Philo 1. OG

Construction of a versatile platform for Rydberg atom experiments — •Aaron Thielmann, Dominik Issler, Erik Bernhart, Sven Schmidt, Thomas Niederprüm, and Herwig Ott — Department of Physics and research center OPTIMAS, RPTU Kaiserslautern-Landau

In recent years, atomic arrays emerged as a ground-breaking platform in quantum physics. These setups feature single-atom control and offer large flexibility to study quantum information processing and many-body physics in different geometric configurations.

We present a new experimental setup utilizing a stainless steel chamber and in vacuum electrodes, allowing to produce arrays of single atoms or small samples, while having as much control over sorrounding parameters as possible. We use holographically generated traps from an SLM at a wavelength of 1064nm, which are projected together with additional addressing beams through a high resolution objective into the vacuum chamber. This opens the possibility to site-selectively excite and deexcite the atoms using multiple two- and three-photon transitions, thus enabling the investigation of transport with controlled dissipation in arbitrarily arranged arrays of Rubidium atoms. Additional features include electric and magnetic field control in combination with an ion detector as well as the ability for global application of microwave and optical fields.

Q 65.4 Thu 17:00 Philo 1. OG

Collectively Enhanced Detection — •Lew Schöne, Amar Bellahsene, Swayangdipta Bera, Clément Gradziel, Maximilian Müllenbach, Shuzhe Yang, Tom Bienaimé, and Shannon Whitlock — Centre Européen de Sciences Quantiques, Institut de Science et d'Ingénierie Supramoléculaire (UMR 7006), Strasbourg, France

Arrays of single atoms in optical tweezers are a strong contestant in the race for quantum computing and simulation platforms (1). Besides their strengths - scalability, environmental isolation and adaptability - the system still lags speed when it comes to qubit manipulation and readout. This project aims to implements a new fast detection scheme to enable measurements on the microsecond timescale.

In the group of Prof. Whitlock in Strasbourg we have experience with arrays of atomic ensembles in microtraps (2). We now want to combine ensembles with single atoms to realize collectively enhanced detection using Rydberg electromagnetically induced transparency (3) to detect the state of a single atomic qubit. The big challenges of this measurement scheme are the preparation of the atomic ensembles and the single atom in neighboring tweezers, as well as an optimized interaction and readout sequence. Implemented on a potassium quantum gas machine, this new detection method will enable fast and state sensitive measurements.

(1) M. Morgado and S. Whitlock, AVS Quantum Science 3, no. 2 (2021)

(2) Y. Wang et al., Npj Quantum Information 6, no. 1 (2020)

(3) W. Xu et al., Physical Review Letters 127, no. 5 (2021)

Q 65.5 Thu 17:00 Philo 1. OG

Study of Rydberg states in ultracold ytterbium — •Nele Koch, Alexander Miethke, Jellina Nuha, and Axel Görlitz — Heinrich-Heine-Universität, Institut für Experimentalphysik, Düsseldorf, Germany

In recent years Rydberg atoms with their special features, like dipole-dipole interaction or van-der-Waals blockade, have become more and more important for quantum optics. Particularly ultracold Rydberg atoms are of great interest for the investigation of long range interaction.

A special feature of ytterbium is that due to its two valence electrons atoms in Rydberg states can be easily manipulated and imaged using optical fields. A first step towards studies of ultracold ytterbium is to gain precise knowledge on the Rydberg states.

Here we present the study of the Rydberg states of ultracold ytterbium. Using a Micro-Channel-Plate to detect the Rydberg atoms it is possible to measure lifetimes and hyperfine structures of several states (n=35-90). In addition we could measure the energy and polarizability of s, p and d states in the region of high principal quantum numbers n (n=70-90). Using a second stage trap we are able to cool the atoms down to several micro K to reduce their distances and investigate interactions.

Q 65.6 Thu 17:00 Philo 1. OG

Towards the simulation of 2D lattice gauge theories in decorated Rydberg tweezer arrays — •Roxana Wedowski[1], Ana Pérez Barrera[1], Quentin Redon[1], Julia Bergmann[1,2], Alessio Celi[1,2], and Leticia Tarruell[1,3] — [1]ICFO - Institut de Ciencies Fotoniques, Castelldefels (Barcelona), Spain — [2]Universitat Autònoma de Barcelona (UAB), Barcelona, Spain — [3]ICREA, Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain

Solving strongly coupled gauge theories in more than one dimension is of fundamental importance in several areas of physics, ranging from high-energy to condensed matter physics. On a lattice, gauge invariance and gauge-invariant interactions involve challenging multi-body interactions to realize in quantum simulators. Engineering generalized blockade interactions in decorated arrays of Rydberg atoms has been proposed as a solution to this challenge. In my poster, I will present our current construction of the strontium Rydberg tweezer platform at ICFO based on this approach. This approach should enable us to realize plaquette interactions and engineer the Rokhsar-Kivelson Hamiltonian with minimal experimental complexity. Specifically, I will discuss our latest progress on the construction of the experimental platform.

Q 65.7 Thu 17:00 Philo 1. OG

Effect of small interaction terms in a time-reversal protocol for a Rydberg Quantum Simulator — •Varad Dhodapkar[1], Maharshi Pran Bora[2], Eduard Braun[3], Meny Menashes[4], Matthias Lotze[5], Gerhard Zuern[6], and Matthias Weidemueller[7] — [1]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [2]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [3]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [4]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [5]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [6]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [7]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg

Time reversal protocols possible one of which is implemented in a dipolar interacting, isolated many-body spin system represented by Ryd-

berg states in an atomic gas. Our time reversal protocol can be used in measurement of Out-of-time-order correlators since time reversal is essential for an OTOC which requires backward evolution of a system which can then be used to measure the extent of information scrambling in the system. However, the dipole-dipole interaction Hamiltonian yields certain second order, perturbative interaction terms which effect the efficiency of our protocol and the fidelity of our measurement. Our goal is to experimentally realize pre-existing theoretical models like a 1-D spin chain to better understand the effect these terms have on our time reversal protocol.

Q 65.8 Thu 17:00 Philo 1. OG

Orientation of Trilobite Rydberg Molecules in Electric Fields — •Markus Exner, Richard Blättner, and Herwig Ott — RPTU Kaiserslautern-Landau, Kaiserslautern, Deutschland

Rydberg molecules consist of a Rydberg atom bound to a ground state atom. The binding mechanism is based on the scattering interaction between the Rydberg electron and the ground state atom. Trilobite molecules are a subclass of high-l Rydberg molecules that exhibit a huge permanent electric dipole moment and are therefore highly sensible to electric fields. We report on the observation of trilobite molecules oriented by an electric field. We excite these molecules within a cloud of ultracold ^{87}Rb atoms using a three-photon excitation scheme. We make the molecules orientation visible on the 2D detector of a reaction microscope taking advantage of state changing collisions.

Q 65.9 Thu 17:00 Philo 1. OG

Towards a global otoc in a rydberg spin system — •Maharshi Pran Bora, Eduard Braun, Meny Menashes, Matthias Lotze, Varad Dhopadkar, Gerhard Zuern, and Matthias Weidemueller — University of Heidelberg

Out-of-time-order correlators (OTOCs) quantify the scrambling of operator information in a quantum system. Most studies formulate this scrambling as a spreading of correlation between local observables in the system. However, the access to these local observables can be challenging sometimes. Interestingly, these correlators can also be studied using global observables of the system. The formulation of multiple quantum coherences and its connection to OTOCs, gives a way to probe the scrambling of global observables in the system [1]. In our Rydberg spin system, we are moving towards measuring this type of global OTOC with a global magnetization measurement. These global OTOC measurements could provide an insight into the localization or thermalization aspects of our rydberg spin system.

[1] Gärttner, M., Hauke, P., & Rey, A. M. (2017). Relating out-of-time-order correlations to entanglement via multiple-quantum coherences. Phys. Rev. Lett. 120, 040402.