A 21: Poster – Atomic Systems in External Fields

Time: Wednesday 17:00–19:00 Location: Tent

A 21.1 Wed 17:00 Tent

Electron-Phonon Coupling and Molecular Dynamics in Rydberg Atom Arrays — •Simon Euchner, Wilson S. Martins, and Igor Lesanovsky — Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany

Rydberg atoms held in optical tweezers feature electronic and vibrational degrees of freedom which can be brought into interaction in a controllable way. Therefore, these systems enable the investigation of dynamical phenomena, similar to those studied in molecular physics, but on exaggerated length and time scales. Beyond certain coupling strengths the vibrational motion becomes unstable, and we derive the critical values. Moreover, we investigate quantum corrections to the ground state energy, which are not captured by the Born-Oppenheimer approximation. Finally, we propose a protocol to prepare molecular states whose structure is strongly affected by the electron-phonon coupling. This shows that trapped Rydberg atom arrays indeed offer a versatile platform for the study of dynamical quantum phenomena that link to molecular physics.

A 21.2 Wed 17:00 Tent

Phase diagram and emergent phenomena in a nonequilibrium three-level Rydberg atom-cavity system — •Paul Haffner[1], Igor Lesanovsky[1,2], and Federico Carollo[3] — [1]Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [2]School of Physics and Astronomy and Centre for the Mathematics and Theoretical Physics of Quantum Non-Equilibrium Systems, The University of Nottingham, Nottingham, NG7 2RD, United Kingdom — [3]Centre for Fluid and Complex Systems, Coventry University, Coventry, CV1 2TT, United Kingdom

Atom-cavity systems are the focus of extensive research due to their rich nonequilibrium dynamics and potential applications in quantum technologies. Here, we investigate a nonequilibrium atom-cavity in which interacting Rydberg states are excited by a combination of the cavity-field and a laser. Using a mean-field approximation, we derive and analyze the nonlinear differential equations governing the system's dynamics. The long-time steady state reveals three distinct phases—stationary states, dark states, and time crystals—with secondorder phase transitions separating them. A stability analysis confirms the robustness of these phases. Finally, we identify a specific fine-tuned condition under which electromagnetically induced transparency accompanied by a dark state emerges.

A 21.3 Wed 17:00 Tent

Quantum orbit theory applied to HATI spectra from metallic nanotips — •Timo Wirth[1], Stefan Meier[1], Jonas Heimerl[1], and Peter Hommelhoff[1,2] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen — [2]Department Physik, Ludwigs-Maximilians-Universität München (LMU), 80799 München

Quantum orbit theory naturally resembles the three-step model for high order above-threshold ionization (HATI). Unlike its classical realization, quantum orbit theory contains the full quantum mechanical information from the strong-field approximation (SFA) and is therefore suitable to explain electron interference effects. Every contribution in quantum orbit theory is connected to an electron trajectory. The metal boundary condition of the nanotip is accounted for through a selection of quantum orbits while near-field effects are discussed in comparison with TDSE simulations. We apply quantum orbit theory to a HATI measurement of a tungsten nanotip illuminated with laser pulses at a central wavelength of 1550 nm. We find clear signs of intracycle interference. We discuss the spectral positions and the magnitude of these interference signals in terms of quantum orbits.

A 21.4 Wed 17:00 Tent

Design and realisation of magnetic field coils for quantum network node experiments — •Vincent Beguin, Raphael Benz, Sebastián Alejandro Morales Ramirez, Micha Kappel, Krishna Relekar, and Stephan Welte — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

The Implementation of a quantum communication network is a challenging task which is addressed in several hardware platforms. Among these, neutral atoms coupled to optical cavities offer a promising approach for realizing quantum networks, with potential applications ranging from distributed quantum computing to secure quantum communication. For these applications, it is crucial to establish well-defined conditions in the spatial region where the atoms are located. In particular, precise control over external magnetic field is essential, as the application of a constant guiding field along the cavity axis is a prerequisite for most experimental protocols.

Here we present the design and implementation of a set of three rectangular magnetic field coils arranged in a Helmholtz configuration. The coils are oriented in three spatial directions, enabling compensation of the Earth's magnetic field and the application of a guiding field along the cavity axis. We characterize important characteristics of our setup, including the heating effects and the field homogeneity within the central region between the coils.

A 21.5 Wed 17:00 Tent

Leveraging of self-supervised machine learning over supervised machine learning for crystalline materials properties prediction. — •Moses Adasariya — Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

The accurate prediction of material properties is essential for the progress of materials science. However, the limited availability of labeled datasets presents a considerable obstacle. This research investigates the capabilities of self-supervised learning (SSL) models to overcome this challenge by utilizing the bulk unlabeled data available for predicting the properties of crystalline materials. Three SSL models were assessed alongside four different supervised learning (SL) model their ability to predict bandgap, formation energy, bulk modulus, and shear modulus. The findings revealed that SSL models consistently outperformed or equaled the performance of SL models across all evaluated tasks. CrysAtom was identified as the most effective model, achieving improvement percentage of 15.1% over orbital graph convolutional neural network (OGCNN) for bandgap, and 9.7% for formation energy over OGCNN. The other SSL models, CT-Barlow and CT-SimSiam, also demonstrated competitive results, particularly in the predictions of bandgap and formation energy. These results underscore the potential of SSL models to diminish dependence on labeled datasets while preserving high levels of prediction accuracy

A 21.6 Wed 17:00 Tent

Photoelectron emission from silver clusters on substrates — •Mikhail Bednov and Dieter Bauer — Institute of Physics, University of Rostock, Germany

We investigate the photoelectron emission from silver clusters of 5 to 15 nanometers in size, deposited on silica substrates with a thin oxidation layer. The particles are illuminated by an 800 nm laser with an intensity of approximately $10\,\mathrm{GW/cm^2}$.

The field distribution is calculated classically using the Green's dyadic method, which provides a good description of electric field enhancement around the particle. This allows us to identify areas of highest field enhancement and calculate the rate of field decay from the particle.

Quantum simulations based on time-dependent density functional theory are performed in one dimension, along the direction of dominant electron emission from corners of the particle where the field enhancement is largest. The aim of these studies is to elucidate the role of the plasmon resonance in the emission process.

A 21.7 Wed 17:00 Tent

Velocity-map imaging of strong-field ionization in standing waves — •Tobias Heldt, Jan-Hendrik Oelmann, Lennart Guth, Lukas Matt, Anant Agarwal, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

To study nonlinear light-matter interactions like multiphoton or tunnel ionization, intense light fields are essential. We employ a femtosecond enhancement cavity to achieve intensities over $10^{13}\,\mathrm{W/cm^2}$ at a 100 MHz repetition rate using a near-infrared frequency comb. The bow-tie cavity supports counter-propagating pulses, forming a transient standing wave at the focus. Here, a gas nozzle and velocity-map imaging (VMI) spectrometer are integrated to analyze the angular distribution of emitted photoelectrons [1].

At the antinodes of the standing wave, constructive interference leads to a doubling of the maximum intensity compared to single pulse operation. Additionally, the ionization region along the beam propagation is reduced because it no longer depends on the Rayleigh length but on the $< 200\,\text{fs}$ overlap of the pulses. This reduction of the focal volume allows momentum imaging without electrostatic focusing [2]. Furthermore, the electrons are diffracted by the structured ponderomotive potential of the standing wave. This phenomenon, known as the Kapitza-Dirac effect, changes the momentum and angular distribution of the photoelectrons.

[1] J.-H. Oelmann et al., Rev. Sci. Instrum., 93(12), 123303 (2022)
[2] T. Heldt et al, Opt. Lett. 49, 6825-6828 (2024).

A 21.8 Wed 17:00 Tent

Generalized Moyal Product in Time-Dependent Electromagnetic Fields — •Arjit Shankar Banerjee[1,2], Andre G. Campos[1], and Christoph H. Keitel[1] — [1]Max Planck Institute for Nuclear Physics, 69117 Heidelberg, Germany — [2]Indian Institute of Science Education and Research (IISER) Tirupati, 517507 Tirupati, Andhra Pradesh, India

The Wigner - Weyl Transformation provides a framework to represent Quantum Mechanical Systems in terms of phase space variables x and p. The Moyal formula defines a nontrivial composition rule that relates the operator product in terms of their Weyl symbols. However, in the presence of electromagnetic fields, the canonical momentum becomes gauge-dependent, but the corresponding operators generally are gauge-independent. Thus, we must redefine the gauge-independent Weyl symbols and the composition rules. While previous works focused on time-independent magnetic fields, we have developed a generalized Moyal product valid for time-dependent electromagnetic fields. An application of the generalized Moyal Product is in the case of Open Quantum Systems, where we are calculating the Lindblad operator in the Foldy-Wouthuysen representation.