FRIAS
FREIBURG INSTITUTE FOR ADVANCED STUDIES
ALBERT-LUDWIGS-UNIVERSITÄT FREIBURG

FRIAS Junior Researcher Conference

QUANTUM CONTROL OF COMPLEX SYSTEMS

September 27-30, 2022

Organized by

Edoardo Carnio
Andreas Woitzik
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Updated: 27.09.22 18:08

Content

1. Programme and generalia

Time	Tue 27.9.22	Wed 28.9.22	Thu 29.9.22	Fri 30.9.22
8:45–9:00		*Opening*		
9:00–9:45		**Laussy**	**Schlawin**	**Schäfer**
9:45–10:30		**Fausti**	**Sanchez**	**Kowalewski**
10:30–11:00		*Coffee*	*Coffee*	*Coffee*
11:00–11:45		**Erath-Dulitz**	**Lentrodt**	**Cao**
11:45–12:30		**Schätz**	**Busto**	*Closing remarks*
12:30–14:00		*Lunch*	*Lunch*	*Lunch*
14:00–14:45		**Ebbesen**	**Lubasch**	
14:45–15:30		**Feist**	**Ritsch**	
15:30–16:00		*Coffee*	*Coffee*	
16:00–16:45		*Free time*	*Free time or city walk*[3]	
16:45–18:30				
Evening	*Welcome Reception*[1]	*Dinner*[2]	*Conference Dinner*[4]	

Useful addresses:
Accommodation: Stadthotel Freiburg, Karlstr. 7, 79104 Freiburg.
Conference venue: FRIAS, Albertstr. 19, 79104 Freiburg.

[1]Welcome reception: 18:30 at FRIAS (Albertstr. 19, 79104 Freiburg).

[2]Dinner: 18:30 at Blauer Fuchs (Metzgerau 4, 79098 Freiburg)

[3]City walk: if the weather allows, we will walk through some of the nice spots of Freiburg.

[4]Conference dinner: 19:00 at Paradies (Mathildenstr. 26-28, 79106 Freiburg).

2. Abstract Overview

Speaker	**Abstract**
David Busto	Attosecond interferometry: from coincidence spectroscopy in molecules to quantum state tomography of photoelectrons
Jianshu Cao	Symmetry in non-equilibrium quantum processes
Thomas W. Ebbesen	Manipulating Matter by Strong Coupling to the Vacuum Electromagnetic Field
Katrin Erath-Dulitz	Study and control of chemi-ionization reactions
Daniele Fausti	Quantum spectroscopies for quantum materials
Johannes Feist	Molecular polaritonics and subwavelength cavity QED
Stefanie Gräfe	CANCELLED: Plasmonic hybrid systems in external light fields
Markus Kowalewski	Photochemistry in the strong coupling regime – building a bottom-up model
Fabrice Laussy	Controlling photon emission
Dominik Lentrodt	Quantum optical few-mode models for lossy resonators
Michael Lubasch	Variational quantum algorithms for industry applications
Helmut Ritsch	A cavity QED based Quantum N-Queens Solver

Carlos Sánchez Muñoz	Squeezed Lasing
Christian Schäfer	Ab initio QED: Controlling Chemistry and Introducing Embedding Radiation-Reaction to Reach Collective Strong Coupling of Large Ensembles
Tobias Schätz	Experimental Quantum Simulations in "Artificial" Arrays of Trapped Ions (and Atoms)
Frank Schlawin	Optimising two-photon absorption with nonclassical light fields
Norbert Schuch	CANCELLED: An entanglement-based perspective on complex quantum systems

3. Abstracts

Attosecond interferometry: from coincidence spectroscopy in molecules to quantum state tomography of photoelectrons

David Busto

University of Freiburg, Germany

The natural timescale for electronic dynamics in matter lies in the attosecond (10^{-18} s) to femtosecond (10^{-15} s) time scale. The discovery of high-order harmonic generation, followed by the first measurements of attosecond pulses at the beginning of the century, opened the opportunity to measure and control electronic dynamics in real time.
Attosecond photoelectron interferometry, in particular the reconstruction of attosecond beating by interference of two-photon transitions (RABBIT), is one of the pillars of attosecond science. It has proved to be a powerful technique to investigate delays in photoemission originating from the interaction of the escaping photoelectron with its parent ion, providing insights into electron-electron correlations [1] in atomic systems.
In recent years, an increasing number of molecular targets have been investigated using RABBIT, showing that this scheme can provide information on electron-nuclear couplings [2] and molecular environment [3]. However, fully resolving the ionization dynamics as a function of emission angle of the photoelectron in the molecular frame is extremely challenging and was only recently achieved [4,5]. In addition, the interpretation of the measurements can be further complicated by the entanglement of the photoelectron with the ion [6].
In the first part of this talk, I will present experiments where we combine photoelectron interferometry and electron-ion coincidence spectroscopy using a Reaction Microscope (ReMi) to investigate the photoionization dynamics of small hydrocarbons in the laboratory frame and in the recoil frame. In particular, we investigate the effect of isotopic substitution in CH_4 and CD_4 on the ionization dynamics. The observed difference between the two isotopologues can be attributed to the difference in the nuclear dynamics occurring in the ion.
In the second part of this talk, I will present a novel interferometric technique, KRAKEN, that allows the quantum state tomography of photoelectrons. Contrary to the RABBIT

technique, our method uses a tunable bichromatic infrared field to induce interference between different energies of a photoelectron wavepacket. We demonstrate our method numerically in the case of ionization in the vicinity of autoionizing resonances in He and Ar and show in the latter case that KRAKEN can quantify the degree of entanglement between the photoelectron and ion [7].

References:

[1] C. Alexandridi et al., Phys. Rev. Reseach **3**, L012012 (2021)
[2] L. Cattaneo et al., Nat. Phys. **14**, 733-738 (2018)
[3] S. Biswas et al., Nat. Phys. **16**, 778-783 (2020)
[4] S. Heck et al., Sci. Adv. **7**, eabj8121 (2021)
[5] H. Ahmadi et al., Nat. Commun. **13**, 1242 (2022)
[6] L. M. Koll et al., Phys. Rev. Lett. **128**, 043201 (2022)
[7] H. Laurell et al., arXiv:2022.06798

Symmetry in non-equilibrium quantum processes

Jianshu Cao

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In this talk, I will briefly summarize our recent progress on light-matter interactions: cavity-catalyzed reactions, disordered polaritons, high-order photon counting statistics, and Floquet dynamics. Then, I will focus on the role of symmetry in quantum transport and optical driving.
Symmetry in molecular systems can result in multiple steady state solutions in non-equilibrium transport measurements. [1] However, dynamic or static disorder in open systems will break the symmetry and thus the degeneracy of multiple steady-states, leading to a unique solution. To reveal the symmetry hidden under disorder, we demonstrate the slow relaxation of dynamical currents and uncover hidden signatures of multiple steady states. [1,2] Another type of symmetry is the commutativity of coupling operators, exemplified by non-commutative quantum transport. [3]
Further, to study the symmetry in laser-driven systems, we have systematically developed Floquet response theory for open quantum systems driven by a strong but periodic driving field and perturbed by a weak but arbitrary probe field. [4,5] Dynamical symmetries of the Floquet states lead to spectroscopic signatures including symmetry-protected dark states and Floquet-band selection rules. [4]

References:
[1] Dynamical signatures of molecular symmetries in nonequilibrium quantum transport. J. Thingna, D. Manzano, and J. Cao, Sci. Rep. 6, 28027 (2016)
[2] Magnetic field induced symmetry breaking in nonequilibrium quantum networks. J. Thingna, D. Manzano, and J. Cao, *New J. Phys.* **22**, 083026 (2020)
[3] Unusual transport properties within noncommutative system−bath coupling operators. C. Duan, C.-Y. Hsieh, J. Liu, J. Wu, and Jianshu Cao, *J. Phys. Chem. Lett.* **11**, 4080 (2020)
[4] Dynamical Symmetries and Symmetry-Protected Selection Rules in Periodically Driven Quantum Systems. G. Engelhardt and J. Cao, *Phys. Rev. Lett.* **126**, 090601 (2021)
[5] Discontinuities in driven spin-boson systems due to coherent destruction of tunneling: breakdown of the Floquet-Gibbs distribution. G. Engelhardt, G. Platero and J. Cao, *Phys. Rev. Lett.* **123** (12), 120602/1-7 (2019)

Manipulating Matter by Strong Coupling to the Vacuum Electromagnetic Field

Thomas W. Ebbesen

USIAS & ISIS, University of Strasbourg, France
CNRS, France

Over the past decade, the possibility of manipulating material and chemical properties by using hybrid light-matter states has stimulated considerable interest. Such hybrid light-matter states can be generated by strongly coupling the material to the spatially confined electromagnetic field of an optical resonator. Most importantly, this occurs even in the dark because the coupling involves the electromagnetic fluctuations of the resonator, the vacuum field. After introducing the fundamental concepts, examples of modified properties of strongly coupled systems, such as superconductivity, magnetism, charge and energy transport, and chemical reactivity will be given to illustrate the broad potential of light-matter states.

References:
[1] F.J. Garcia Vidal, C. Ciuti, T.W. Ebbesen, Science **2021**, 373, eabd336
[2] K. Nagarajan, A. Thomas, T.W. Ebbesen, J. Am. Chem. Soc. **2021**, 141, 16877.

Study and control of chemi-ionization reactions

Katrin Erath-Dulitz

Institut für Ionenphysik und Angewandte Physik, University of Innsbruck, Austria
Institute of Physics, University of Freiburg, Germany

Ultracold mixtures of different atomic species are used to obtain dense samples of ultracold heteronuclear molecules which may feature long-range and anisotropic interactions. Such interactions allow for new physics and chemistry studies in a regime purely dominated by quantum effects. To achieve the co-trapping of ultracold atoms, reactive collisions must be efficiently suppressed.
As a first step towards co-trapping, we study the chemi-ionization of ultracold Li by metastable He (He*). For this, we combine a supersonic-beam source for He* with a magneto-optical trap for Li [1]. We use optical pumping to deplete the population in the metastable 2^1S_0 state of He [2], and to prepare Li($2^2S_{1/2}$) and metastable He(2^3S_1) in selected magnetic sub-levels prior to the collision [3].
In this contribution, I will show the efficient control of He*-Li chemi-ionization at thermal energies using spin- and quantum-state preparation. Our results imply a strong suppression (enhancement) of chemi-ionization for non-spin-conserving (spin-conserving) reaction channels [4]. The results are in good agreement with a model based on spin angular momentum coupling of the prepared atomic states to the molecular reaction channels. Small deviations from the model are indicative for spin-violating effects. The ionization rate also decreases when Li is laser-excited to the $2^2P_{1/2,3/2}$ states. This is due to the conservation of the projection of the total molecular orbital angular momentum along the internuclear axis [5].
I will also present an experimental scheme aimed at coherently controlling the chemi-ionization of selected atoms and diatomic molecules by He(2^3S_1).

References:
[1] J. Grzesiak et al., "Penning collisions between supersonically expanded metastable He atoms and laser-cooled Li atoms", J. Chem. Phys. 150, 034201 (2019).
[2] J. Guan et al., "Optical quenching of metastable helium atoms using excitation to the 4P state", Phys. Rev. Appl. 11, 054037 (2019).
[3] T. Sixt et al., "Preparation of individual magnetic sub-levels of 4He(23S1) in a supersonic beam using laser optical pumping and magnetic hexapole focusing", Rev. Sci. Instrum. 92, 073203 (2021).
[4] T. Sixt et al., "Spin-state-controlled chemi-ionization reactions between metastable helium atoms and ground-state lithium atoms", J. Chem. Phys. 156, 114306 (2022).

[5] K. Dulitz et al., “Suppression of Penning ionization by orbital angular momentum conservation”, Phys. Rev. A 102, 022818 (2020).

Quantum spectroscopies for quantum materials

Daniele Fausti

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University of Trieste, Italy
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The rich phase diagrams of many transition metal oxides (TMOs) is the result of the intricate interplay between electrons, phonons, and magnons. This makes TMOs very susceptible to external parameters such as pressure, doping, magnetic field, and temperature which in turn can be used to finely tune their properties. The same susceptibility makes TMOs the ideal playground to design experiments where the interaction between tailored electromagnetic fields and matter can trigger the formation of new, sometimes exotic, physical properties. This aspect has been explored in time domain studies [1] and has led to the demonstration that ultrashort mid-IR light pulses can "force" the formation of quantum coherent states in matter, disclosing a new regime of physics where thermodynamic limits may be bridged and quantum effects can, in principle, appear at ambient temperatures.
In this presentation, I will review our recent results in archetypal strongly correlated cuprate superconductors and demonstrate the feasibility of a light-based control of quantum phases in real materials [2,3,4]. I will then introduce our new approaches to time domain spectroscopy going beyond mean photon number observables [5-10] and show that the statistical features of light can provide richer information than standard linear and non-linear optical spectroscopies [11]. Finally, I will elaborate on our current directions on leveraging both the electromagnetic field fluctuations and the strong driving of materials to control the onset of quantum coherent states in complex materials.

References:
[1] Advances in physics 65, 58-238, 2016
[2] Science 331, 189-191 (2011)
[3] Phys. Rev. Lett. 122, 067002 (2019)
[4] Nature Physics 17, 368–373 (2021)
[5] Phys. Rev. Lett. 119, 187403 (2017)
[6] New J. Phys. 16 043004 (2014)
[7] Nat. Comm. 6, 10249 (2015)

[8] PNAS March 19, 116 (12) 5383-5386 (2019)
[9] J. of Physics B 53, 145502 (2019)
[10] Optics Letters 45, 3498 (2020)
[11] Light: Science & Applications, 11, 44 (2022)

Molecular polaritonics and subwavelength cavity QED

Johannes Feist

Universidad Autónoma de Madrid, Spain

When the interaction of molecular excitations with confined light modes becomes sufficiently large, the strong-coupling regime is entered and the eigenstates of the system become hybrid light-matter excitations, so-called polaritons. In wavelength-scale optical cavities, such polaritons are delocalized states that arise due to the collective interaction of macroscopic numbers of molecules with the same light mode and thus have fundamentally different characteristics than the single-molecule excitations that they are formed from. Polariton formation thus provides a control knob that can be used to affect a number of material properties without having to modify the material itself. I will discuss several examples of such effects, including changes of the absorption and emission characteristics of a material, of energy transfer between molecular species, and of photochemical reactions. A second experimental platform is provided by plasmonic nanocavities that confine light to strongly subwavelength dimensions. This increases the light-matter interaction sufficiently that the strong-coupling regime can be reached with just one or a few molecules. In these cases, the energy level structure and dynamics of the molecule are affected even more strongly than in the collective case, allowing control of the states and dynamics of single quantum systems. At the same time, ultrafast losses are unavoidable in such cavities, leading to additional loss-induced effects. I will discuss several strategies to not only mitigate but exploit these fast losses.

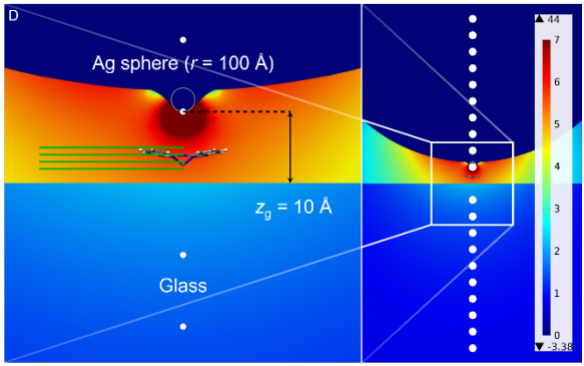
CANCELLED

Plasmonic hybrid systems in external light fields

Stefanie Gräfe

Institute for Physical Chemistry and Institute of Applied Physics, Friedrich Schiller University Jena, Germany

The excitation of collective electron dynamics inside the metallic nanoparticles induced by external light fields leads to strongly re-shaped electromagnetic nearfields with a complex spatial and temporal profile. The interaction of these modified and enhanced nearfields with systems located in close vicinity to the metallic nanoparticle is the origin of many astonishing physical and chemical phenomena, such as the formation of new quasi-particles, new mechanisms for chemical reactions or the ultra-high spatial resolution and selectivity in molecular detection.
Besides being of fundamental interest, this interplay between nearfields and molecules promises great potential on the application side, potentially enabling breakthrough in new emerging technologies in a broad range of research fields, such as nanophotonics, energy and environmental research, biophotonics, light-harvesting energy sources, highly sensitive nano-sensors etc. This necessitates a solid theoretical understanding and simulation of these hybrid systems.
For the theoretical description of such plasmonic hybrid systems in external light fields, it is necessary to describe both the electromagnetic interaction and the more chemical effects equally. In this talk, I will introduce our recent results on the theoretical description of these systems, with particular emphasis on spectroscopic applications, e.g., in the context of tip-enhanced Raman scattering spectroscopy: several recent experiments provide evidence for an extremely high spatial resolution of this setup on the nanometer or even sub-nanometer scale. Our calculations show pronounced changes of the Raman spectrum under non-resonant and resonant conditions and support the possibility of sub-nanometer spatial resolution.



References:
[1] K. Fiederling, M. Abasifard, M. Richter, V. Deckert, S. Gräfe, S. Kupfer, "A Full Quantum Mechanical Approach Assessing the Chemical and Electromagnetic Effect in TERS", Nanoscale, **2020**, 12, 6346.
[2] F. Latorre, S. Kupfer, T. Bocklitz, D. Kinzel, S. Trautmann, S. Gräfe, V. Deckert, „Spatial resolution of tipenhanced Raman spectroscopy – DFT assessment of the chemical effect", Nanoscale **2016**, 8, 10229.

Photochemistry in the strong coupling regime – building a bottom-up model

Markus Kowalewski

Stockholm University, Sweden

We have investigated a number of molecular systems in the last few years with regard to the strong cavity coupling. While it seems to be widely accepted that collective interactions play a major role in strong coupling photochemistry, other effects are less well explored. Our theoretical studies have shown that, for example, limited photon lifetimes, dipole self interactions, or vibrational strong coupling seems to play a role. We will give an overview over our studies and discuss the influence of these effects.

Controlling photon emission

Fabrice Laussy

University of Wolverhampton, United Kingdom

When looking at the power spectrum of an optical source, one looks at its one-photon emission. If this is classical light, one could be looking at its two-, three-, ..., N-photon emission and still see the same thing. If this is quantum light, however (non-Gaussian states), one could see totally unrelated spectra depending on which photon-order the observation is made. From this realization, one can hope to implement a new way to control photon emission, such as transporting at the one-photon level (the one where the signal is strong) the features of the higher orders, invisible to the "naked" (single) detector, to such a point that most quantum-optician are even unaware of their existence. I will present our understanding of photon emission as applied to the simplest nontrivial case, resonance fluorescence in the high (Mollow) driving regime, and discuss basic strategies to get a grip on how quantum emitters release their photons.

Quantum optical few-mode models for lossy resonators

Dominik Lentrodt

University of Freiburg, Germany

Few-mode models - such as the Jaynes-Cummings model and its generalisations - have been an indispensable tool in studying the quantum dynamics of light-matter interactions in optical resonators and provide the theoretical basis for many control studies. Recently, however, novel regimes featuring strong coupling in combination with large losses have attracted attention in various experimental platforms. In this context, central assumptions of these canonical quantum optical models have to be revisited.
In this talk, we will discuss recent extensions of Jaynes-Cummings type few-mode models and an associated class of loss-induced multi-mode effects. In particular, we will introduce an exact basis transformation to derive few-mode theory from first principles and a simple classification criterion for the appearance of multi-mode effects in lossy resonators. We will further discuss open problems, the relation to alternative approaches, and implications for recent experiments in x-ray cavity QED with Mössbauer nuclei - an emerging platform at the high-energy frontier of quantum optics, featuring lossy resonators doped with ultra-low decoherence emitters.

Variational quantum algorithms for industry applications

Michael Lubasch

Cambridge Quantum Computing Ltd., United Kingdom

Variational quantum algorithms have become a popular approach to make use of current quantum computers. In this talk I give an overview of our work [1-4] that was motivated by industry projects relating to chemistry, machine learning, optimization and finance.

References:
[1] M. Benedetti, M. Fiorentini, and M. Lubasch, "Hardware-efficient variational quantum algorithms for time evolution", Phys. Rev. Research 3, 033083 (2021).
[2] M. Benedetti et al., "Variational inference with a quantum computer", Phys. Rev. Applied 16, 044057 (2021)
[3] D. Amaro et al., "Filtering variational quantum algorithms for combinatorial optimization", Quantum Sci. Technol. 7, 015021 (2022).
[4] K. Plekhanov et al., "Variational quantum amplitude estimation", Quantum 6, 670 (2022).

A cavity QED based Quantum N-Queens Solver

Valentin Torggler, Philipp Aumann, Elias Starchl, Wolfgang Lechner, and **Helmut Ritsch**

Institute for Theoretical Physics, University of Innsbruck, Austria

The N-queens problem is to find the position of N queens on an N by N chess board such that no queens attack each other. The excluded diagonals N-queens problem is a variation where queens cannot be placed on some predefined fields along diagonals. The problem is proven NP-complete and for the excluded-diagonals variation the parameter regime to generate hard instances that are intractable with current classical algorithms is known. We propose a special purpose quantum simulator that implements the excluded diagonals N-queens completion problem using atoms in an optical lattice and cavity-mediated long-range interactions. Our implementation has no overhead from the embedding allowing to directly probe for a possible quantum advantage in near term devices for optimisation problems. In specific examples we show that a successful quantum annealing process relies on atom-field entanglement and works superior to semi-classical approximations.

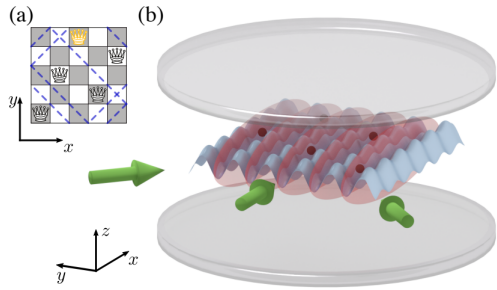


FIG. 1. *Sketch of the setup.*

Acknowledgments:
Simulations were performed using QuantumOptics.jl. Research was funded by the Austrian Science Fund (FWF) and the EU Horizon2020.

Squeezed Lasing

Carlos Sánchez Muñoz

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The laser, originally described to be as a "solution seeking a problem", is now a ubiquitous piece of technology and arguably one of the most successful practical applications of quantum mechanics. The key property behind its success is its capability to provide high-intensity light with a narrow linewidth and long coherence times. In this talk, I will discuss our proposal of a squeezed laser [1], a device in which a macroscopic photonic occupation powered by stimulated emission develops in a squeezed cavity mode. I propose a possible implementation in the optical regime and discuss the quantum-optical properties of the emission. Above the lasing threshold, the emitted light retains both the line narrowing and frequency stabilization characteristic of a laser, but also the photon correlations characteristic of a photonic mode with squeezed quadratures. This combination of characteristics opens new possibilities for applications in quantum metrology and spectroscopy.

References:
[1] Squeezed Lasing. Carlos Sánchez Muñoz and Dieter Jaksch. Phys. Rev. Lett. 127, 183603 (2021).

Ab initio QED: Controlling Chemistry and Introducing Embedding Radiation-Reaction to Reach Collective Strong Coupling of Large Ensembles

Christian Schäfer

University of Technology, Göteborg, Sweden

Hybridizing light with molecular excitations provides a novel handle to non-intrusively control chemistry. The complexity of chemical reactions and the interaction of large numbers of molecules in electromagnetic environments renders a theoretical description challenging, to put it mildly. This challenge gave birth to a new discipline, sometimes referred to as 'ab initio QED', on the interface of condensed matter and quantum optics. As one of the first applications, we have been able to leverage ab initio QED to shine light on the microscopic mechanism that allows the modification of chemical reactivity under vibrational strong coupling [1]. Our approach recovers main features of the experimental observations, including the previously elusive resonant condition. However, the computational cost of high-level ab initio QED prohibited thus far a faithful representation of large molecular ensembles. I will demonstrate a simple shortcut to ab initio QED based on the radiation-reaction approach [2, 3]. The latter is trivial to combine with existing quantum-chemistry libraries, paving a way for collective light-matter dynamic described from first principles. A simple proton-tunneling reaction serves as illustrative example that the modification of chemical reactivity under vibrational strong coupling can feature a complex dependence on the number of ensemble emitters.

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References:
[1] Schäfer C., Flick J., Ronca E., Narang P., and Rubio A., arXiv:2104.12429 (2021).
[2] Schäfer C. and Johansson G., Phys. Rev. Lett. 128, 156402, (2022).
[3] Schäfer C., J. Phys. Chem. Lett. 13, 30, 6905–6911 (2022).

Experimental Quantum Simulations in "Artificial" Arrays of Trapped Ions (and Atoms)

D. Palani, **Tobias Schätz**, U.Warring

University of Freiburg

Direct experimental access to some of the most intriguing and puzzling quantum phenomena is difficult due to their fragility to noise. Their efficient simulation on conventional computers might be impossible, since quantum behaviour is not efficiently translatable in classical language. However, to reach beyond the capabilities of very powerful numerical methods and approximations, leading theorists of the field demand more than one-dimensional systems linked via interactions at long range and the study of complex quantum dynamics, respectively. In these systems, we could still gain deeper insight into complex quantum behaviour via experimentally simulating it in another quantum system. Here, not all but the relevant parameters and interactions might be controlled and robust effects detected sufficiently well.

Trapped atomic ions are among the most promising candidates to provide a platform for experimental quantum simulations, featuring unique control as well as operational fidelities in one-dimensional systems of few-ions. We aim to scale this system to larger size and dimensionality while preserving the unique controllability via trapping individual ions (atoms) at individual sites of arrays—on the one hand, by trapping above radio-frequency surface traps with electrodes of the micrometer scale, on the other hand, by confining them within optical lattices (potentially combining them with atoms).

After a general introduction to the field, we will present our recent results on coupling individually trapped, coherently excited ions within a basic-triangular array. The aim is to increase the system ion-by-ion, loading additional sites in slightly larger arrays of 7-10 ions, scaling towards 100 sites. While investigating the correlations of complexity and scaling, we might start to study spin-frustration within quantum spin Hamiltonians and Aharonov Bohm physics via tunnelling phonons. In addition, we will present our results on studying the onset of thermalisation and its time scales in closed quantum systems in dependence on their "size" – here still in conventional rf-traps. We will discuss in detail the challenges/limitations and prospects for our approaches.

Optimising two-photon absorption with nonclassical light fields

Frank Schlawin

Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany

We will present a brief overview of the physics of two-photon absorption (TPA) with nonclassical light, in particular with entangled photon pairs. We will explain why in the latter case it scales linearly with the photon flux at small light intensities, suggesting a means to carry out nonlinear spectroscopy with much reduced intensities. We then argue why it has proven challenging to observe this potential quantum enhancement in molecular systems to date, and then present two possible avenues to overcome this problem:

(1) We will discuss how to optimally shape entangled states of light in resonant TPA [1], and exploit the nonclassical bandwidth properties of broadband entangled photon pairs to enhance the absorption probability beyond the optimal classical limit.

(2) We will describe how we can use quantum metrology to find optimal observables for TPA detection and describe a possible implementation in nonlinear interferometers [2].

References:

[1] E. G. Carnio, A. Buchleitner, and FS, SciPost Core 4, 028 (2021)

[2] S. Panahiyan, C. S. Muñoz, M. V. Chekhova, and FS, arXiv 2205.10576; in preparation (2022)

CANCELLED

An entanglement-based perspective on complex quantum systems

Norbert Schuch

University of Vienna

Complex quantum systems and the correlations they exhibit – quantum entanglement – play a key role both in quantum information and quantum computing and in exotic phenomena observed in quantum many-body systems. This common theme has stimulated a growing exchange between these two fields: On the one hand, the study of entanglement theory has given rise to new perspectives from which to study quantum many-body systems; on the other hand, the investigation of complex quantum systems forms a prime candidate both for the benchmarking and as an application of near-term quantum computers and simulators. In my talk, I will give an introduction to this growing field at the intersection of quantum information and many-body physics and highlight some recent results which make use of their interplay.

4. Participant List

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