SFB

FoQuS

Foundations and Applications of Quantum Science

43rd SFB meeting

18-19 October 2018, Innsbruck

Contents

43rd SFB FOQUS Meeting		
18 - 19.10.2018 Lecture Hall C, EG, Technikerstraße 25, Innsbruck		
Thursday 18.10		
14:00	Armando Rastelli	*Semiconductor quantum dots for quantum photonics applications* (40’+10’)
14:50	Borivoje Dakic	*Few-copy entanglement detection* (20’+5’)
15:15	Mariusz Semczuk	*Towards detection and characterization of ultracold mixtures with heterodyne interferometers* (20’+5’)
15:40	Poster flash presentations (15’)	
15:55	**Coffee break & poster session (35’)**	
16:30	Hartmut Häffner	*Coherent control of rotating ion strings: towards observing quantum statistics in a new regime* (40’+10’)
17:20	Elvia Colella	*Spontaneous cavity-mediated antiferromagnetism in a two component Fermi gas* (20’+5’)
17:45	Uros Delic	*Levitated cavity optomechanics in high vacuum* (20’+5’)
18:10	Transport (**Tram 3** or bus O)	
19:00	**Conference Dinner** Theresienbräu, Maria-Theresien-Straße 51, Innsbruck	
Friday 19.10		
08:30	**Business Meeting**	
09:30	Philipp Treutlein	*Optomechanics with optical lattices and nanomechanical membranes* (40’+10’)
10:20	Ilya Kull	*A spacetime area law bound on quantum correlations* (20’+5’)
10:45	Maximilian Sohmen	*Dipolar quantum mixtures of Erbium and Dysprosium* (20’+5’)
11:10	**Coffee break & poster session (35’)**	
11:45	Peter Kirton	*Efficient non Markovian quantum dynamics using time-evolving matrix products operators* (20’+5’)
12:10	Yijian Meng	*Cold-atom-based implementation of the Dicke model in the ultra-strong coupling regime* (20’+5’)
12:35	Pietro Silvi	*Probing quantum critical dynamics on a programmable Rydberg simulator* (20’+5’)
13:00	End of the meeting	

TALK ABSTRACTS

Thursday 18th October

14:00

Semiconductor quantum dots for quantum photonics applications

Armando Rastelli, Johannes Kepler University Linz, Austria

Semiconductor quantum dots (QDs) obtained by epitaxial growth are regarded as one of the most promising solid-state sources of triggered single and entangled photons for applications in emerging quantum communication and photonic quantum-information-processing.
In this talk, I will introduce the "features and bugs" of QDs in view of their potential applications, followed by a presentation of some of our recent results. In particular, I will focus on GaAs QDs in AlGaAs matrix [1,2], which show a unique combination of appealing features: fast radiative rates of ~5 GHz, capability of generating near perfectly entangled photon pairs [3] with excellent indistinguishability and ultralow multiphoton emission probability [4], as well as wavelength matched to the high-sensitivity range of silicon-based single-photon detectors and optical transitions of Rubidium atoms [5]. I will also show that some of the QD "bugs" can be fixed by integrating them onto piezoelectric actuators [6-7]. Strain provided by such actuators is a powerful tool to bring the emission energy of separate dots into resonance [8], to restore broken symmetries [7], and also to change the polarization properties of the emitted photons [9]. I will conclude by discussing the open challenges.

References

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[2] Y. H. Huo et al. Appl. Phys. Lett. 102, 152105 (2013); Y. Huo et al. Nature Phys. 10, 46 (2014).
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[4] L. Schweickert, et al. Appl. Phys. Lett. 112, 093106 (2018).
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[8] M. Reindl et al. Nano Lett. 17, 4090 (2017).
[9] X. Yuan et al. Nat. Comm. 9, 3058 (2018).

14:50

Few-copy entanglement detection

Borivoje Dakic, Institut für Quantenoptik und Quanteninformation, Vienna.

Quantum technologies lead to a variety of applications that outperform their classical counterparts. In order to build a quantum device it must be verified that it operates below some error threshold. Recently, because of technological developments which allow for the experimental realization of quantum states with increasing complexity, these tasks must be applied to large multi-qubit states. However, due to the exponentially-increasing system size, tasks like quantum entanglement verification become hard to carry out in such cases. One of the main reasons is that the conventional detection methods (based on entanglement witnesses) require large statistics (i.e. many copies of the quantum state) to extract expectation values of witness operators. Moreover, almost all the standard techniques assume that every detection event is identical and independent, a situation that is challenging to achieve in practice. In this talk, I will present a probabilistic verification scheme [1,2] which enables reliable entanglement verification in a more realistic scenario, where the number of copies is finite and rather small. I will show that the confidence to verify the presence of entanglement grows exponentially fast with the number of individual detection events (copies of quantum state). At the end, I will present a recent experiment performed to benchmark our theoretical findings, were we experimentally verify the presence of entanglement in a photonic six-qubit cluster state. We found that (some) entanglement can be certified with at least 99.74% confidence by detecting around 20 copies of the quantum state. Additionally, we found that genuine six-qubit entanglement is verified with at least 99% confidence by using around 112 copies of the state. Our protocol can be carried out with a remarkably low number of copies, making it a practical and applicable method to verify entanglement in large-scale quantum devices.

References

[1] A. Dimić and B. Dakić, Single-copy entanglement detection, npj Quantum Information 4, 11 (2018),

[2] V. Saggio, A. Dimić;, C. Greganti, L. A. Rozema, P. Walther, and B. Dakić, Experimental few-copy multi-particle entanglement detection, arXiv:1809.05455, (2018).

15:15

Towards detection and characterization of ultracold mixtures with heterodyne interferometers

Mariusz Semczuk, University of Warsaw, Poland.

Many experiments in ultracold physics rely on destructive detection, in particular absorption imaging. This limits the typical data acquisition rate to one measurement every 10-20 seconds, limited by the sample preparation time. In the talk I will discuss an alternative method of detection that exploits the phase shift induced by atoms on an off-resonance probe beam with respect to a co-linear reference beam of different frequency, resulting in a phase shift of the detected beat note. The change in the density of the trapped atomic cloud and hence the atom number can be detected by such heterodyne interferometer with negligible heating of the sample. Based on the observation that in many experiments the only figure of merit is the change in the trapped atom number, cameras typically used for detection can be replaced or at least supplemented, by photodiodes. The method can shorten the data acquisition time by removing the need for multiple repetitions of the experimental sequence. It should allow measurements with high time resolution reaching several microseconds in a single experimental realization thanks to the implementation of photodiodes as detectors. The scheme presented in the talk is particularly useful when the studied processes lead to atom loss or change of population to a state not interacting with the light used in the interferometer. Typical examples of application are photoassociation spectroscopy, temperature and lifetime measurements.

16:30

Coherent control of rotating ion strings: towards observing quantum statistics in a new regime

Hartmut Häffner, UC Berkeley, USA.

Typically, the bosonic or fermionic nature of indistinguishable particles is either relevant at atomic scales or when the wavefunctions of the particles overlap. Two ions in an ion string, however, are always separated by several micrometers making it natural to identify them as individual particles. In order to demonstrate that the two ions may need to be treated as the same, we plan to interfere an ion string with itself rotated by 180 degrees. In view of this goal, we prepare ion strings rotating with angular momenta of about 7,500 ± 30 quanta. The fast rotation allows for coherent control of the rotational degree-of-freedom making it possible to interfere the ion string with its rotated version.

17:20

Spontaneous cavity-mediated antiferromagnetism in a two-component Fermi gas

Elvia Colella, University of Innsbruck.

We propose the realization of spin and density self-ordering for a gas of multi-level fermionic atoms coupled to a two-mode ring resonator. The system is characterized by a continuous translational symmetry U(1) determined by the cavity geometry, along with a discrete spin inversion symmetry $\mathbf{Z}_2$, realized by the choice of the pumping configuration. The combined $\mathbf{Z}_2$ x U(1) symmetry is spontaneously broken at the onset of the phase transition where the superradiance follows the emergence of self-organized structures in the spin and density channel. The dynamical coupling between the cavity modes and the atomic state favours the emergence of an antiferromagnetic lattice commensurate to the cavity wavelength. The appearance of a local dependent magnetization in the transverse direction and the decrement of the global magnetization above threshold confirm the antiferromagnetic character of the stationary ground state. At last, we analyse the momentum correlations between particles with same and opposite spins. The strong correlations mediated by the photons are damped at high pump strength, indicating the decoherence in momentum space of the two particles indirectly coupled through the light fields.

17:45

Levitated cavity optomechanics in high vacuum

Uroš Delić, University of Vienna.

Although cavity cooling of levitated nanospheres has been demonstrated in recent years [1, 2], regime of strong optomechanical cooperativity C>1 is yet to be reached, leading to full quantum control of nanosphere motion. A common obstacle in many experiments is stable levitation of nanospheres in ultra-high vacuum (UHV). However, stable trapping has been achieved in an optical dipole trap in several experiments through the use of three-dimensional parametric feedback [3]. We exploit this by combining such a trap with an optical cavity and demonstrate cavity optomechanics with a silica nanosphere at the onset of UHV. Using extreme stability of our setup, we confirm trapping of nanospheres of nominal radius through a novel method which exploits both linear and quadratic coupling to cavity mode. We measure unprecedented high cooperativity of C=0.02, showing a five orders of magnitude improvement of cooperativity from our previous work [1]. I will discuss current limitations and simple improvements needed to reach strong cooperativity in the not too distant future.

References:

[1] Kiesel et al., PNAS 110: 14180-14185 (2013)
[2] Millen et al., Phys. Rev. Lett. 117, 173602 (2016)
[3] Gieseler et al., Phys. Rev. Lett. 109, 103603 (2012), Jain et al., Phys. Rev. Lett. 116, 243601 (2016)

Friday 19th October

09:30

Optomechanics with optical lattices and nanomechanical membranes

Philipp Treutlein, University of Basel.

Radiation pressure forces mediated by light are a versatile tool for engineering interactions between mechanical systems of different nature. We report experiments where we observe such light-mediated interactions between atoms in an optical lattice as well as between atoms and a nanomechanical membrane. By engineering a long-distance coupling between the membrane vibrations and the collective motion of ultracold atoms in an optical lattice, we realize a hybrid mechanical system with new functionality [1]. We demonstrate sympathetic cooling of the membrane from room temperature to 650 mK by coupling it to laser-cooled atoms in the lattice [2]. In lattices with large numbers of atoms, we observe that light-mediated atom-atom interactions lead to collective motion in the lattice [3]. This leads to dynamical instabilities, as predicted by theoretical work of Ritsch and coworkers [4]. We discuss the perspectives for quantum control in such systems.

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[3] A. Vochezer, T. Kampschulte, K. Hammerer, and P. Treutlein, Phys. Rev. Lett. 120, 073602 (2018).

[4] J. Asboth, H. Ritsch, and P. Domokos, Phys. Rev. A 77, 063424 (2008).

10:20

A spacetime area law bound on quantum correlations

Ilya Kull, Institut für Quantenoptik und Quanteninformation, Vienna.

Area laws are a far-reaching consequence of the locality of physical interactions, and they are relevant in a range of systems, from black holes to quantum many-body systems. Typically, these laws concern the entanglement entropy or the quantum mutual information of a subsystem *at a single time*. However, when considering information propagating in spacetime, while carried by a physical system with local interactions, it is intuitive to expect area laws to hold for spacetime regions; in this work, we prove such a law in the case of quantum lattice systems. We consider a sequence of local quantum operations performed at discrete times on a spin-lattice, such that each operation is associated to a point in spacetime. In the time between operations, the time evolution of the spins is governed by a finite range Hamiltonian. By considering a purification of the quantum instruments and analyzing the quantum mutual information between the ancillas used in the purification, we obtain a spacetime area law bound for the correlations between the measurement outcomes inside a spacetime region, and those outside of it.

10:45

Dipolar quantum mixtures of Erbium and Dysprosium

Maximillian Sohmen, Institut für Quantenoptik und Quanteninformation, Innsbruck.

In recent years, atoms with a large permanent magnetic dipole moment such as the rare-earth elements erbium and dysprosium, have attracted much attention as model systems to study dipolar interactions on a quantum level. We present a new quantum gas experiment, which is the first to combine Er and Dy in a single apparatus. It allows both single- and double species operation, and features three different science chambers, one for quantum gas mixtures in the bulk, one for ultracold Rydberg atoms, and one for quantum gas microscopy.

With this experiment, we demonstrate doubly-degenerate Bose-Bose mixtures in five different Er-Dy isotope combinations, as well as a doubly-degenerate Er-Dy Bose-Fermi mixture. Finally, we present first studies of the interspecies interaction between the two elements.

11:45

Efficient non-Markovian quantum dynamics using time-evolving matrix product operators

Peter Kirton, Vienna University of Technology.

In order to model realistic quantum devices it is necessary to simulate quantum systems strongly coupled to their environment. To date, most understanding of open quantum systems is restricted either to weak system-bath couplings, or to special cases where specific numerical techniques become effective. I will present a novel, general numerical approach to efficiently describe the time evolution of a quantum system strongly coupled to a non-Markovian environment.
By writing the path integral description of the history of the system as a large tensor, we use matrix product based techniques to develop our method, called 'time-evolving matrix product operators' (TEMPO) [1]. This allows us to efficiently calculate dynamics of generic open systems, making it applicable to simulations of a wide variety of physical systems. In this talk I will give an overview of how the TEMPO algorithm works and show the power and flexibility of our method by numerically identifying the BKT localisation transition of the Ohmic spin-boson model for both spin-1/2 and spin-1.

[1] Strathearn, Kirton, Kilda, Keeling & Lovett, Nat. Commun. 9, 3322, (2018)

12:10

Cold-atom-based implementation of the Dicke model in the ultra-strong coupling regime

Yijian Meng, Vienna University of Technology.

The interaction between quantum emitters and a single quantized electromagnetic field mode is at the heart of quantum optics. When the interaction strength approaches the frequency of the bosonic mode, the so called ultra-strong coupling regime emerges, where new physical phenomena are expected. To systematically investigate light-matter interaction at this extremely large coupling strength, tunable system parameters and preparation of the initial state are highly desirable. In this context, we demonstrate that optically trapped cold atoms constitute a promising model system where the atom's motional quanta are used as an analogue of the photons, and the Zeeman substates of the atom take the role of the electronic states of two-level atoms. If, due to spatially varying polarization, the trapping light field induces strong gradients of the vector ac Stark shift, coupling between the atom's motion and spin occurs. This mechanism is formally equivalent to the atom-photon coupling encountered in cavity quantum electrodynamics.

We will present experiments taking advantage of this spin-motion coupling to manipulate cold Cesium atoms in a nanofiber-based optical trap. In the first experiment, we implement degenerate Raman cooling, which we can either do via an external or a fiber-guided light field. The final temperature of the atoms can be inferred from a fluorescence spectroscopy measurement. It indicates cooling of the atoms close to the motional ground state in all spatial dimensions. In the second experiment, we demonstrate spin-motion coupling strengths which are a significant fraction of the mode (trap) frequency, which sets our system clearly in the ultra-strong coupling regime. Furthermore, we show that the coupling strength can be readily and independently tuned in situ. Beyond their fundamental interest, our results pave the way for implementing protocols and applications that exploit extreme coupling strengths.

12:35

Probing quantum critical dynamics on a programmable Rydberg simulator

Pietro Silvi, Institut für Quantenoptik und Quanteninformation, Innsbruck.

Quantum phase transitions (QPTs) involve transformations between different states of matter that are driven by quantum fluctuations. These fluctuations play a dominant role in the quantum critical region surrounding the transition point, where the dynamics are governed by the universal properties associated with the QPT. The resulting quantum criticality has been explored by probing linear response for systems near thermal equilibrium. While time dependent phenomena associated with classical phase transitions have been studied in various scientific fields, understanding critical real-time dynamics in isolated, non-equilibrium quantum systems is of fundamental importance both for exploring novel approaches to quantum information processing and realizing exotic new phases of matter. Here, we use a Rydberg atom quantum simulator with programmable interactions to study the quantum critical dynamics associated with several distinct QPTs. By studying the growth of spatial correlations while crossing the QPT at variable speeds, we experimentally verify the quantum Kibble-Zurek mechanism (QKZM) for an Ising-type QPT, explore scaling universality, and observe corrections beyond simple QKZM predictions. This approach is subsequently used to investigate novel QPTs associated with chiral clock model providing new insights into exotic systems, and opening the door for precision studies of critical phenomena and applications to quantum optimization.

POSTER ABSTRACTS

Certification and Quantification of Multilevel Quantum Coherence

Martin Ringbauer, University of Innsbruck

Quantum coherence is one of the fundamental features that mark the departure of quantum mechanics from the classical realm. It manifests whenever a system exists in a superposition of classically distinguishable states, and for many-body systems embodies the essence of entanglement. For gauging the nonclassicality of a system, however, it is important to go beyond the mere presence or absence of coherence. Just like in the case of entanglement, there is a rich structure of multilevel coherence, which might be interesting for applications in quantum information processing and beyond. Using four-dimensional quantum systems we demonstrate a number of ways to experimentally quantify multilevel coherence. In particular, multilevel coherence is found to be the fundamental resource for an elementary quantum information task, which in turn can be exploited to witness the presence of coherence even without knowing what your measurement device is doing.

Cavity QED in the non-perturbative regime

Daniele de Bernardis, University of technology, Vienna

We study a generic cavity-QED system where a set of (artificial) two-level dipoles is coupled to the electric field of a single-mode LC resonator. This setup is used to derive a minimal quantum mechanical model for cavity QED, which accounts for both dipole-field and direct dipole-dipole interactions. The model is applicable for arbitrary coupling strengths and allows us to extend the usual Dicke model into the non-perturbative regime, which can be associated with an effective finestructure constant of order unity. In this regime we identify and characterize three distinct classes of normal, superradiant and subradiant vacuum states and study the transitions between them. Our findings reconcile many of the previous, often contradictory predictions on this topic and provide a unified theoretical framework to describe ultrastrong coupling phenomena in a large variety of physically very different cavity-QED platforms.

Subradiance in multilevel V-type systems

Raphael Holzinger, University of Innsbruck.

Spontaneous emission in quantum emitters is modified by other atoms nearby, leading to super- and subradiance. We demonstrate the subradiant behaviour of V-type multilevel emitters in close vicinity to each other, with specific examples being the equilateral triangle and the linear chain at inter-atomic distances smaller than the transition wavelength between the atomic states. For the equilateral triangle it is shown, that a analytical treatment is possible for a very symmetric configuration. In this setup the Hamiltonian has a maximally entangled, antisymmetric eigenstate involving the superpositions of all three atoms which shows subradiance as opposed to superradiance. Moreover, it decouples completely from the vacuum radiation field and therefore does not decay spontaneously. Numerical simulations involving different dipole orientations and interatomic distances are presented and their subradiant behaviour is investigated.

A Quantum N-Queens Solver

Valentin Torggler, University of Innsbruck

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 are known. We propose a special purpose quantum simulator with the aim to solve the excluded diagonals N-queens completion problem using atoms 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 optimization problems.

Multipartite state generation in quantum networks with optimal scaling

Julius Wallnöfer, University of Innsbruck

We introduce a repeater scheme to efficiently distribute multipartite entangled states in a quantum network with optimal scaling. The scheme allows to generate graph states such as 2D and 3D cluster states of growing size or GHZ states over arbitrary distances, with a constant overhead per node/channel that is independent of the distance. The approach is genuine multipartite, and is based on the measurement-based implementation of multipartite hashing, an entanglement purification protocol that operates on a large ensemble together with local merging/connection of elementary building blocks. We analyze the performance of the scheme in a setting where local or global storage is limited, and compare it to bipartite and hybrid approaches that are based on the distribution of entangled pairs. We find that the multipartite approach offers a storage advantage, which results in larger rates and better performance in certain parameter regimes. We generalize our approach to arbitrary network topologies and different target graph states.

Observation of Roton Mode Population in a Dipolar Quantum Gas

Daniel Petter, University of Innsbruck

Dipolar Bose-Einstein condensates (dBECs) offer an ideal playground for investigating novel aspects of many-body phenomena in the presence of dipole-dipole interactions (DDI). A seminal work in 2003 [1] predicted the existence of a roton mode (a minimum in the dispersion relation at a finite momentum k_{rot} with an energy Δ_{rot}) in the excitation spectrum of a dBEC, similar to the roton mode in superfluid He II. In contrast to He II, the roton mode in a dBEC does not require strong interactions, but rather arises from the momentum dependence of the DDI. In our experiment, we use dBECs of 166Er, confined in a cigar-shaped trap. In order to investigate the roton mode, we employ a Feshbach resonance to quench down the scattering length a_s into a regime, where k_{rot} vanishes and eventually becomes imaginary. At this point, the roton mode population starts to exponentially grow with time. We probe the roton mode in the momentum distribution of the atomic cloud and observe two distinct peaks at $+/-k_{rot}$ appearing, when quenching below a critical as. From the time-resolved population we are able to directly extract the imaginary Δ_{rot}. By repeating the measurements in different configurations, we experimentally probe the characteristic scalings of the roton mode with the trapping length scale along the direction of the atomic dipoles and a_s. We compare our results with an analytical model and full real-time simulations, and unambiguously confirm the roton nature of the observed mode [2].

[1] L. Santos et. al., PRL 90, 250403 (2003)
[2] L. Chomaz, et. al., Nature Physics, 14, 442 – 446 (2018)

Quantifying the momentum correlation between two light beams by detecting one

Armin Hochrainer, Institut für Quantenoptik und Quanteninformation, Vienna

We present a method for measuring the momentum correlation between two photons by detecting only one of them. It can be applied even if one of the photons possesses a wavelength, for which no suitable detector is available. The method is based on the phenomenon of induced coherence without induced emission. A photon pair is created in a superposition of two origins. By aligning the paths of one of the photons to be indistinguishable, an interference pattern is created in the superposition of paths of the other photon. We show that the momentum correlation between both photons can be determined by analyzing this interference pattern, although one of the photons remains undetected. The results show that information about the correlations in a photon pair can be accessed by measurements on only one of its constituents, given the pair can be created by two identical sources.

Symmetry properties of graph states

Matthias Englbrecht, University of Innsbruck

Abstract: In order to understand the capabilities of graph states under LOCC and thus to find new applications for them, it is essential to characterize the local symmetries for this class of states. We aim to identify the different types of local symmetry groups and to understand how they affect the structure of the corresponding graph. In particular, we show that in addition to graph states with a continuous symmetry group and graph states with just the stabilizer, there are states with a finite local symmetry group larger than the stabilizer. The considered examples are LC equivalent to the Reed Muller states, which due to their additional symmetry are interesting for fault-tolerant quantum computing. Eventually we want to use the insights gained from these considerations to construct graph states with other symmetries and find applications for them.

Atomic double twin beams

Filippo Borselli, TU Wien

The main goal is to generate pairs of Bell-entangled atoms. Our experiment is the atomic analog of the parametric down-conversion process, widely used in quantum optics. A Bose-Einstein condensate plays the role of the laser and the non-linearity is provided by interactions between atoms. In a previous experiment, we generated twin-atom beams in momentum space formed of quantum correlated atom pairs showing reduced fluctuations in number difference. Here, we want to use a double-well potential to define an additional spatial mode separation: the left and the right well of the double well. Atomic pairs are emitted into double twin beams, characterized by four different modes (two distinct momenta plus two different spatial modes) and expected to be in a Bell-entangled state.

Variational cooling

Viacheslav Kuzmin, Institut für Quantenoptik und Quanteninformation, Vienna

We investigate variational preparation of a circuit which unconditionally cools a system of qubits to the ground state of a given Hamiltonian. In comparison with the standard variational method exploiting only unitary operations, our method uses auxiliary qubits, which are entangled with the "system" qubits by unitary gates and afterward are coupled to the physical environment. Optimizing the parameters of the unitary operations, we achieve cooling of the "system" qubits to the desired pure state. The developed algorithm is suitable for various platform, including a system of Rydberg atoms.

Trapped-ion simulation of the Extended Dicke Model

Tuomas Jaako, Atominstitut , Vienna

We propose to simulate the Extended Dicke Model with systems of trapped ions. Especially we concentrate on simulation of the single qubit ultra-strong coupling regime with, on average, repulsive dipole-dipole interactions. In this regime in the ground state of the system the light and matter degrees of freedom are decoupled and at the same time the qubits are highly entangled among themselves. We highlight some experiments that could be done such as an adiabatic preparation of the ground state, and quench-dynamics. Different aspects of the spectrum of the system could be studied by probing either the ions or the normal modes of the ion crystal.

Spinor quantum gases of dipolar fermions

Alexander Patscheider, University of Innsbruck

We present an experimental study of a spinor dipolar gases, using for the first time highly magnetic fermionic atoms in a three-dimensional optical lattice. We use the fermionic isotope of erbium, ^{167}Er, loaded in the lowest band of a deep lattice with a central region of unit filling. We detail the preparation scheme for producing a versatile spin mixture of the two lowest Zeeman sublevels, i.e. m_F=-19/2 and -17/2, starting from a spin polarized degenerate sample in m_F=-19/2. We report on the behavior of the mixture when varying the external uniform magnetic field. From bulk loss-spectroscopy measurements on different mixtures, we identify interspin Feshbach resonances in addition to the dense spectra of intraspin resonances [1]. In particular, we find one comparatively broad interspin Feshbach resonance on which we focus. Using lattice modulation spectroscopy, we perform a first measurement of the interspin interaction strength. By exploiting the dipolar dependence on the dipole orientation (controlled by the magnetic-field direction), we identify the respective contributions of dipolar and contact interactions to the onsite energy. We then map the interspin scattering length variations, both in magnitude and in sign, across the broad interspin Feshbach resonance. Finally, we report on first measurements of the spin dynamics driven by dipolar offsite interactions in the deep three-dimensional lattice. Flip-flop dynamics with conserved magnetization is observed and a resonance behavior evidences the role of quadratic light shifts. The high degree of control achieved in our dipolar spinor system opens fascinating prospects for the exploration of quantum dipolar magnetism and spin-ordered phases.

[1] S. Baier et al., arxiv:1803.11445 (2018).

Towards the realisation of an atom trap in the evanescent field of a WGM-microresonator

Lukas Masters, TU Wien.

Whispering-gallery-mode (WGM) resonators guide light by total internal reflection and provide ultra-high optical quality factors in combination with a small optical mode volume. Coupling a single atom to the evanescent field of a WGM microresonator thus allows one to reach the strong coupling regime [1]. Furthermore, such resonators provide chiral light-matter coupling which can be employed for realising novel quantum protocols [2] as well as nonreciprocal quantum devices [3]. However, trapping atoms in the evanescent field of such resonators has not yet been demonstrated, which severely limits the atom-resonator interaction time. We aim to trap single 85Rb atoms in the vicinity of a bottle-microresonator using a standing wave optical dipole trap which is created by retroreflecting a tightly focussed beam on the resonator surface [4]. In order to load atoms into the trap, we employ an FPGA-based electronics which allows us to react in 150 ns to an atom arriving in the resonator field and thus to switch on the dipole trap. We will present first characterisations of our trap and discuss methods for detecting and cooling the atoms in the resonator. [1] C. Junge et al. Phys. Rev. Lett. 110, 213604 (2013). [2] I. Shomroni et al. Science 345, 903 (2014) . [3] M. Scheucher et al. Science 354, 1577 (2016). [4] J. D. Thompson et al. Science 340, 1202 (2013)

Modular architectures for quantum networks

Alexander Pirker, University of Innsbruck

We consider the problem of generating multipartite entangled states in a quantum network upon request. We follow a top-down approach, where the required entanglement is initially present in the network in form of network states shared between network devices, and then manipulated in such a way that the desired target state is generated. This minimizes generation times, and allows for network structures that are in principle independent of physical links. We present a modular and flexible architecture, where a multi-layer network consists of devices of varying complexity, including quantum network routers, switches and clients, that share certain resource states. We concentrate on the generation of graph states among clients, which are resources for numerous distributed quantum tasks. We assume minimal functionality for clients, i.e. they do not participate in the complex and distributed generation process of the target state. We present architectures based on shared multipartite entangled Greenberger-Horne-Zeilinger (GHZ) states of different size, and fully connected decorated graph states respectively. We compare the features of these architectures to an approach that is based on bipartite entanglement, and identify advantages of the multipartite approach in terms of memory requirements and complexity of state manipulation. The architectures can handle parallel requests, and are designed in such a way that the network state can be dynamically extended if new clients or devices join the network. For generation or dynamical extension of the network states, we propose a quantum network configuration protocol, where entanglement purification is used to establish high-fidelity states. The latter also allows one to show that the entanglement generated among clients is private, i.e. the network is secure.

Directions

To the Technik campus:

The Technik campus can be reached from the Hauptbahnhof (central station) in about 20 minutes with the **Tram 3**, direction Peerhofsiedlung or Technik West. Exit at the stop "**Technik**".

The SFB meeting takes place in the **Lecture Hall C**, on the ground floor of the Viktor-Franz-Hess Haus (see Technik campus map on the next page).

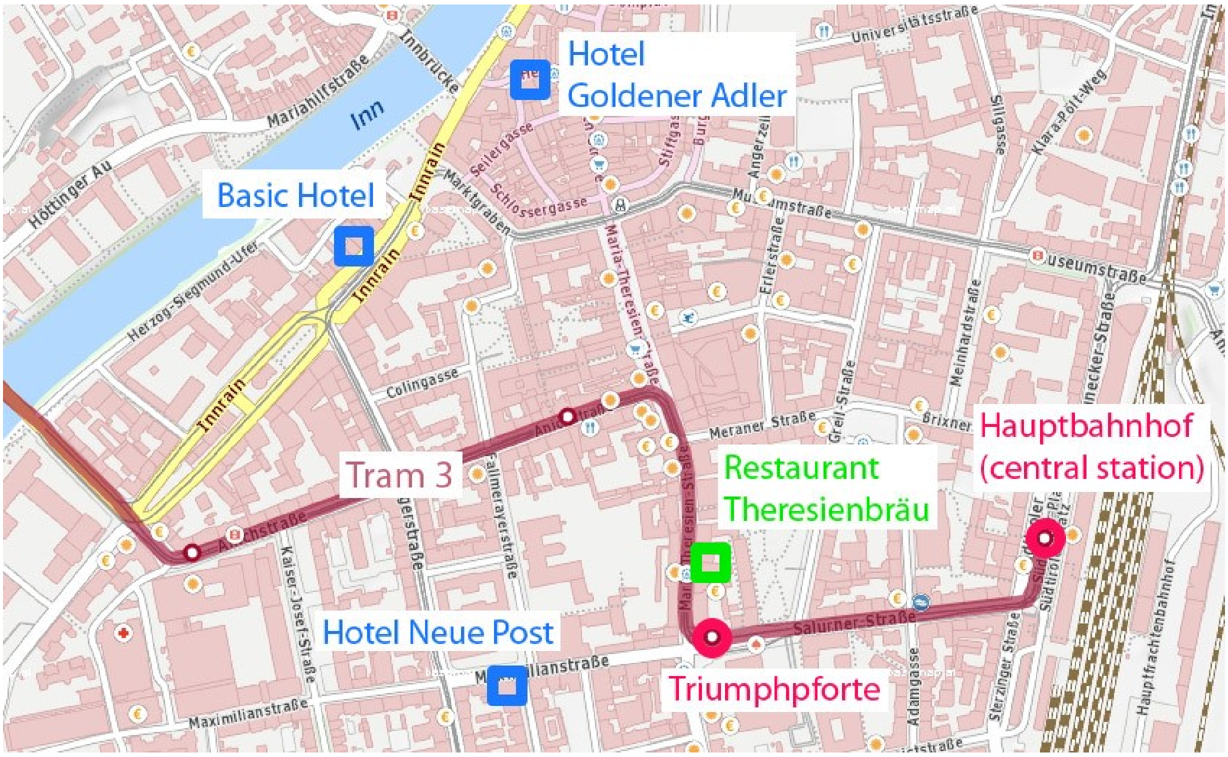
To the conference dinner:

From the Technik campus to the Restaurant **Theresienbräu** (Maria-Theresien-Straße 51), take the **Tram 3** at the stop "Technik" direction Amras, and exit at the stop "**Triumphpforte / Casino**".

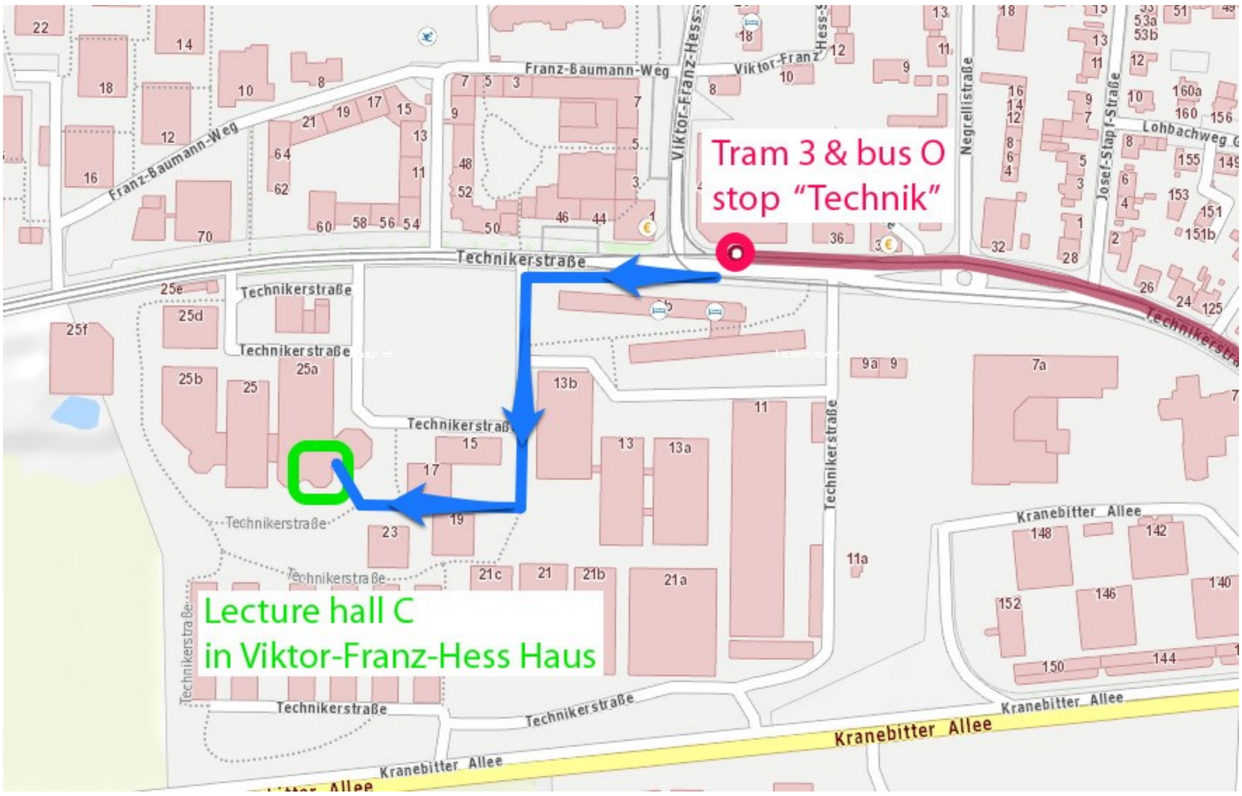
To the hotels:

From the Technik campus to the **Basic Hotel** and to the **Hotel Goldener Adler**, take the **Bus O** at the stop "Technik" direction J.-Kerschb.-Straße and exit at "**Terminal / Marktplatz**". Both hotels are 15 min away from the restaurant Theresienbräu. The **Hotel Neue Post** is close to the restaurant Theresienbräu (see above).

Overview map



City center



Technik campus