THE FIRST JOINT COQUS AND IMPRS-QST VIENNA

SUMMER SCHOOL

ON COMPLEX QUANTUM SYSTEMS

TU WIEN, ATOMINSTITUT, VIENNA

18TH - 22ND SEPTEMBER 2017

POSTER SESSIONS

LIST OF ABSTRACTS

Poster Session 1 – Monday 18th 1600-1830

M1 **Adarsh Prasad** CoQuS, TU Wien

Towards the investigation of collective scattering in nanofiber-trapped atomic ensembles

We realize an efficient optical interface between guided light and laser-cooled atoms which are arranged in two linear arrays in a two-color evanescent-field dipole trap created around an optical nanofiber. In this configuration, the probability of a nanofiber-guided photon being absorbed and then re-emitted into free space by a trapped atom can be as high as 10%.For a periodic array of atoms, interference of the fields scattered by different atoms result in a collective emission into a cone with a well-defined angle with respect to the fiber axis. Our simulations show that the collective emission pattern loses its azimuthal symmetry when there are two arrays of trapped atoms. The angle of the collective emission with respect to the fiber axis also varies depending on the trapping periodicity and the probe wavelength. We plan to study this collective emission and its dependence on various experimental parameters. The next step will be to adjust the periodicity of the atomic array to fulfill the Bragg condition such that fiber-guided light is strongly back-reflected. Here, the interaction between the atomic array and the fiber-guided light depends strongly on the polarization of the light field. In particular, light that is polarized in the plane of atoms will be weakly reflected and the component orthogonal to the plane of atoms will be strongly reflected. We want to implement such highly reflecting atomic arrays, which could then be used to implement cavity quantum electrodynamics experiments in which the mirrors themselves are made of quantum emitters.

M2 **Alexander Schuckert** IMPRS-QST, MPQ

Non-equilibrium dynamics of spin-systems using 2PI effective action methods

We study the time evolution of interacting spin systems, one of the paradigmatic models for quantum many-body dynamics appearing e.g. in quantum magnetism. We use the Schwinger boson representation to map general spin-spin Hamiltonians with arbitrary spin length to a scalar field theory. By using resummation methods for the 2PI effective action we compute the time evolution of the magnetization and exchange field correlators. Our first application is an inhomogeneous long-range dipolar XY spin system in an external driving field, which has recently been implemented with cold Rydberg atoms.

Poster Session 1 – Monday 18th 1600-1830

M3 **Anna Pearson** University of Oxford

Circuit Optomechanics with Silicon Nitride Membranes

Exploiting the resonant enhancement of light-matter interaction, cavity optomechanics opens new possibilities ranging from ground state cooling of macroscopic mechanical resonators to gravitational wave detection. Circuit optomechanics operates in the microwave regime and has the advantage of being on chip and easily incorporated into cryogenic setups. A radio-frequency circuit allowed us to probe the vibrations of a nm-thick silicon nitride membrane at room temperature.We explore the feasibility of a bench-top experiment based on this optomechanical setup at cryogenic temperatures to explore the nature of gravity in the quantum domain and its role in quantum motion. Should gravity interact classically with quantum systems the resulting decoherence of position leading to diffusion (heating) in momentum would give an anomalous density dependent heating effect.

M4 **Anna Hackenbroich** IMPRS-QST, MPQ

Projected Entangled Pair State for a chiral spin liquid

Projected Entangled Pair States (PEPS) are a class of ansatz states that are very useful for numerical simulations of two-dimensional systems. While many non-chiral models with topological order possess exact PEPS representations, it is not clear whether similar constructions can exist for chiral topological systems. We study a chiral spin-singlet PEPS for a system of spin-1/2 whose entanglement spectrum possesses gapless chiral modes that display the same state counting as the bosonic 1/2 Laughlin state. Since this PEPS has algebraically-decaying correlation functions on the square lattice, it displays features both of criticality and of chiral topological order.

Poster Session 1 – Monday 18th 1600-1830

M5 **Annabelle Bohrdt** IMPRS-QST, TUM

Single-hole excitation spectra of spin-chains

We propose a measurement scheme to experimentally access the momentum and energy resolved spectral function in a quantum gas microscope with currently available techniques. We furthermore present numerical results for the excitation spectrum of a single hole in an antiferromagnetic spin chain. In finite systems, spin-charge separation can be observed across the entire spectrum and a full resolution of the spinon dispersion is possible. Remarkably, a sharp asymmetry in the distribution of spectral weight, reminiscent of pseudogap phenomenology in two-dimensional cuprates, appears for the isotropic Heisenberg spin chain. We discuss a slave-fermion mean field theory for quantum spin liquids that captures the essential features of the observed behavior.

M6 **Armin Hochrainer** CoQuS, University of Vienna

Quantifying the momentum correlation between two light beams by detecting one

We measure the transverse momentum correlation between two photons by detecting only one of them. In our experiment, photon pairs are created in a coherent superposition of two identical sources. Using the phenomenon of induced coherence without induced emission, we produce an interference pattern by superposing one beam from each source. This allows us to access information about bi-photon properties in the single photon count rate. Our approach could be useful for the characterization of photon pair sources and may lead to an experimental measure of continuous-variable entanglement, which relies on the detection of only one of two entangled particles. The paper is: Hochrainer, A., Lahiri, M., Lapkiewicz, R., Lemos, G.B. and Zeilinger, A. (2017): "Quantifying the momentum correlation between two light beams by detecting one". PNAS, 114(7), 1508-1511.

M7 **Asli Cebe** IMPRS-QST, MPQ

Asli Cebe — IMPRS-QST, MPQ

Ensembles with Maximal Renyi Entropies

The Gibbs ensemble, describing thermal equilibrium states, can be formulated variationally as the one that maximizes von Neumann entropy, given a certain energy density. One could instead construct other ensembles that maximize different entropic quantities and respect thesame constraints. One particular case, which could be of special interest for the numerics, is theensemble maximizing 2 - Renyi entropy. We construct such ensembles and study their properties.

M8 **Bertrand Evrard** LKB Collège de France

Antiferromagnetic quantum phase transition in a one dimensional spinor Bose gas

Ultracold atom systems are excellent candidates to investigate the underlying physical mechanisms of spatial organization in quantum phases of matter. Ultracold spinor gases (systems with an internal spin degree of freedom) exhibit a rich landscape of quantum phases. In such systems, the competition between the spin dependent interaction energies and the hyperfine Zeeman energies, gives rise to a quantum phase diagram of generalized magnetic phases. In one dimensional system, anti-ferromagnetic interactions induce immiscibility of the Zeeman states and the creation spin-domain. We study the formation of such domains and their sensitivity to magnetic field gradient.

Poster Session 1 – Monday 18th 1600-1830

M9 **Claudio Benzoni** IMPRS-QST, TUM

New Insights on Rotating BECs

Rotating atomic BECs have been experimentally realizable since 15 years ago ca. However, up to now only little effort has been put to topologically characterize their excitations. The system explicitly breaks parity and time-reversal symmetries and breaks spontaneously rotational invariance via the formation of the vortex lattice. Unlike quantum Hall fluids, the system is compressible. The endeavour is to evaluate transport and edge properties by approaching the problem both by the microscopic (Gross-Pitaevskii) theory and from an effective field theory viewpoint. The Nambu-Goldstone bosons for the low-energy theory are the Tkachenko modes: elliptically polarized vortex-lattice vibrations with soft (quadratic) dispersion. The usual phononic branch is not present since it is redundant to the TK. The system can also be investigated using the dual gauge description using two-dimensional boson-vortex duality.

M10 **Daniele de Bernardis** CoQuS, TU Wien

Dipolar systems in the ultra-strong coupling regime

In this work we propose a generalized Dicke model, consisting in a system of artificial two levels dipoles capacitively coupled to a resonant circuit. The dipole-dipole interaction makes possible to reach the superradiance phase transition, which corresponds to a ferroelectric transition for the polarization in the ground state. With the appropriate geometry it is possible to switch from a ferroelectric ground state to an anti-ferroelectric one, which correspond to the so called lightmatter decoupling phase. For a finite system it is of particularly interested the border region between the superradiant and the light-matter decoupling phases. Indeed here quantum fluctuations are prominent, with possible observations of squeezing in the ground state magnetic flux of the circuit resonator. We argue that this simple model represent the minimal model to describe the physics of cavity QED using artificial atoms.

M11 **David Grass** CoQuS, University of Vienna

Optical trapping and control of nanospheres inside hollow core photonic crystal fibers

We report a hollow core photonic crystal fiber (HCPCF) based optical conveyor belt for levitated nano-particles in vacuum. An optical read-out allows monitoring the three-dimensional motion of the particle over the entire fiber length and is used for radiation pressure based feedback cooling. Besides the target application of controlled and clean delivery of nano-particles into ultra-high acuum for levitated optomechanical systems we utilize read-out and feedback cooling to investigate the local pressure along the fiber when a pressure gradient is applied. We compare the measurements with predictions from a direct simulating Monte Carlo (DSMC) method of the nonlinear Boltzmann equation.

M12 **Dimitri Pimenov** IMPRS-QST, LMU

Unmasked quantum criticality - the FFLO superconductor-normal metal fixed point.

Many technologically relevant materials show signatures of "strange metal" phases, where strong quantum fluctuations decohere the usual Fermi-liquid quasiparticles. Such phases are found near quantum critical points, and can be modelled by coupling a gapless bosonic order parameter field to fermions. Here, we study a particular example, the strange metal fixed point of a normal metal - FFLO superconductor transition in a 2D system. This transition can be realized by applying a in-plane magnetic field, which first renders the superconductor inhomogeneous with nonzero wavevector, and eventually destroys superconductivity upon further increase of the field strength. Applying the controlled dimensional regularization scheme introduced by Dalidovich and Lee, we perform a renormalization group analysis of an effective low-energy theory for the transition, determine its critical properties and discuss competing instabilities. We expect that this transition is particularly suited for experimental observation, since one can tune through it simply by changing the magnetic field strength. What is more, the fixed point should not be masked by a superconducting dome, in contrast to strange metal fixed points studied before.

M13 **Dominik Irber** IMPRS-QST, TUM

Towards Improved Readout of a Single Electron Spin in Diamond by Pulsed Multicolor Laser Excitation

The nitrogen-vacancy (NV) center in diamond can serve as quantum sensor for magnetic fields down to the nuclear spin signal of nanometer-sized samples. These measurements require the readout of the NV spin state, which can be easily performed optically as its fluorescence is spin dependent even at room temperature. However, this simple readout is very inefficient requiring several 100 repetitions. We present our efforts to improve readout efficiency, focusing on spin to charge conversion (SCC) as an alternative to the direct fluorescence readout. Doing so, pulsed multicolor laser ionization protocols promise improved readout contrast at lower laser power. In addition, I will discuss prospects of optical manipulation of the spin transition, which could lead to implementing coherent population trapping and electromagnetically induced transparency in the solid state at ambient temperatures.

M14 **DongKeun Lee** Sogang University

Numerical evaluation of the localizable entanglement in 1D spin chain model

The Localizable entanglement (LE), suggested by Verstraete (2004), is a measure of multipartite entanglement which is into pairwise entanglement between two spins. The property of the LE is that the tightly lower bound of the LE measured by the concurrence is the maximal correlation function between two parties, which implies that LE can detect the many-body physics more subtly than the maximal correlation function does. Generally speaking, it is non-trivial to calculate LE numerically due to the difficulty for the optimal choices of measurement bases. Here, a new approach is proposed to overcome a limited number of parties and a exponential number of measurement outcomes.

Poster Session 1 – Monday 18th 1600-1830

M15 **Eleanor Crane** University College London

Controlling qubits of a silicon-based digital quantum computer with dopant Rydberg states.

Quantum information processing in a condensed matter system can be implemented in silicon, benefiting scalability. The Rydberg states of dopant phosphorous valence electrons, controlled with THz light, can entangle two neighbouring arsenic valence electrons which serve as qubits, realizing a CNOT gate. We show long coherence times by observing Rabi oscillations and performing Ramsey spectroscopy on the atomic two level system of the phosphorous donors with a Free Electron Laser, using optical as well as electrical detection techniques. We broaden our understanding of the system by accessing the band structure of phosphorous 2D electron gas in silicon via ARPES.

M16 **Emely Wiegand** Chalmers University of Technology

Limits of the lifetime enhancement of an atom in front of a mirror

The spontaneous emission of an atom depends on the density of states of the electromagnetic modes of the environment. In ref [1], an artificial atom was coupled to a 1D-transmission line whose density of states was modified by grounding it at one end. It models a system of an atom in front of a mirror. The effective distance of the atom to the mirror can be varied by changing the effective transition frequency of the transmon. Close to the node of the electromagnetic field, the coupling became small and could no longer be measured. In this work, we calculate the residual coupling of the atom at the node, using a circuit model for the transmon coupled to a semi-infinite transmission line.

[1] http://rdcu.be/tQaY

M17 **Esteban Castro** CoQuS, University of Vienna

Dynamics of quantum causal structures

It was recently suggested that causal structures are both dynamical, because of general relativity, and indefinite, due to quantum theory. The process matrix formalism furnishes a framework for quantum mechanics on indefinite causal structures, where the order between operations of local laboratories is not definite (e.g. one cannot say whether operation in laboratory A occurs before or after operation in laboratory B). Here we develop a framework for "dynamics of causal structures", i.e. for transformations of process matrices into process matrices. We show that the causal order between a subset of operations can be changed under continuous yet nonreversible transformations. An explicit example is that of the quantum switch, where a party in the past affects the causal order of operations of future parties, leading to a transition from a channel from A to B, via superposition of causal orders, to a channel from B to A. However, we show that under continuous and reversible transformations the causal order between operations is always preserved. We generalise our framework to construct a hierarchy of quantum maps based on transformations of process matrices and transformations thereof.

M18 **Fabian Kugler** IMPRS-QST, LMU

Multiloop fRG that sums up all parquet diagrams

We present multiloop flow equations for the four-point vertex and self-energy in the functional renormalization group (fRG) framework. The multiloop flow consists of successive one-loop calculations and is equivalent to a solution of the (first-order) parquet equations in conjunction with the Schwinger-Dyson equation for the self-energy. We numerically demonstrate its improvement over one-loop fRG using the X-ray-edge singularity as prototypical model to study the interplay between different two-particle channels.

M19 **Federica Cataldini** CoQuS, TU Wien

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M20 **Georg Wachter** University of Vienna

Scalable Silicon Microcavities for Quantum Systems

We have fabricated a arrays of silicon microcavities with high finesse (over 140000). These mirrors are produced by a scalable plasma etch process, yielding small radii of curvature below 20 micrometers and consequently strong enhancement of the optical field per photon. The purpose of these microcavities is to investigate light-matter coupling, with the aim of creating large-scale quantum processors based on cavity quantum electrodynamics.

Poster Session 1 – Monday 18th 1600-1830

M21 Hui Wang Dartmouth College

Quantum Dynamics of a Josephson Junction-Driven Cavity Mode System in the Presence of Voltage Bias Noise

We give a semiclassical analysis of the average photon number as well as photon number variance (Fano factor F) for a Josephson-junction (JJ) embedded microwave cavity system, where the JJ is subject to a fluctuating (i.e. noisy) bias voltage with finite dc average. Through the ac Josephson effect, the dc voltage bias drives the effectively nonlinear microwave cavity mode into an amplitude squeezed state (F < 1), as has been established previously [A. D. Armour et al., Phys. Rev. Lett. 111, 247001 (2013)], but bias noise acts to degrade this squeezing. We find that the sensitivity of the Fano factor to bias voltage noise depends qualitatively on which stable fixed point regime the system is in for the corresponding classical nonlinear steady state dynamics. Furthermore, we show that the impact of voltage bias noise is most significant when the cavity is excited to states with large average photon number.

M22 Irati Alonso Calafell University of Vienna

The one in which the pigeon and the message do not travel together

In classical communication the pigeon always brings the message with it. In counterfactual communication, on the other hand, the pigeon and the message do not travel in the same direction. Based on the quantum Zeno effect and interaction-free measurements, Arvidsson-Shukur et al. have recently developed a new protocol, where Alice sends a pigeon to Bob and Bob sends a message to Alice. Nevertheless, counterintuitively, there is no trace of the pigeon flying back from Bob to Alice. Here, we show an experimental implementation of this protocol based on a completely reconfigurable state of the art silicon-on-insulator waveguide.

M23 **Ivana Kurecic** IMPRS-QST, MPQ

Z3 topological order from local SU(3) symmetries on the Kagome lattice

Topological order is a special kind of zero-temperature phase of matter with long-range quantum entanglement; it's characterized by a robust ground state degeneracy and the local indistinguishability of its ground states. Because of its unique properties, it continues holding a coveted place among the hot research topics in both condensed matter physics and quantum information.It has been shown that Z2 topological order can be realized in a system of interacting SU(2) spins in triangular lattices. In this poster, I present an approach to investigating the existence of Z3 topological order in a spin system of a local SU(3) symmetry, by use of tensor network methods.

M24 **Jakob Hinney** CoQuS, TU Wien

Towards the investigation of collective scattering in nanofiber-trapped atomic ensembles

We realize an effient optical interface between guided light and lasercooled atoms which are arranged in two linear arrays in a two-color evanescent-fild dipole trap created around an optical nanofiber. In this confiuration, the probability of a nanofiber-guided photon being absorbed and then re-emitted into free space by a trapped atom is as high as 10%. For a periodic array of atoms, interference of the fields scattered by different atoms results in a collective emission into a cone with a well-defined angle with respect to the fiber axis. We plan to study this collective emission and its dependence on various experimental parameters. The next step will be to adjust the periodicity of the atomic array to fulfill the Bragg condition such that fiber-guided light is strongly back-reflected. Here, the interaction between the atomic array and the fiber-guided light depends strongly on the polarization of the light field. In particular, light that is polarized in (orthogonal to) the plane of atoms will be weakly (strongly) reflcted. We want to implement such highly reflcting atomic arrays, which could then be used to implement cavity quantum electrodynamics experiments in which the resonator itself is made of quantum emitters.

M25 **Jonas Zeuner** CoQuS, University of Vienna

Integrated Heralded Controlled-NOT Gate for Polarization-Encoded Qubits

Recent progress in integrated-optics technology has made photonics one of the most promising candidates for scalable quantum computation. Waveguides feature small device footprints and intrinsic interferometric stability combined with the ability to control light at the single-photon level. Here, we use femtosecond-laser-written waveguides, whose unique ability to process polarization-encoded qubits enables easy interfacing with bulk-optic polarization entanglement sources. We present the first implementation of an integrated-optic heralded controlled-NOT gate that can scalably create and analyze polarization-entangled states. We address coupling loss due to mismatch of the waveguide modes and standard single-mode fiber modes, a problem common to many integrated-optics experiments, using thermally-expanded-core fibers. We fully characterize the gate's behavior in the computational basis and demonstrate its ability to entangle two photons' polarizations.

M26 **Julian Huber** CoQuS, TU Wien

PT-symmetry breaking in open quantum systems

We study the quantum mechanical version of a prototype PT -symmetric system consisting of two coupled harmonic oscillators with balanced loss and gain. By introducing a physically consistent class of master equations to describe such a scenario, we analyze the transient dynamics and the steady states of this system in the regime where quantum noise associated with the gain process plays a dominate role. In particular, we show that the phenomenon of steady-state PT - symmetry breaking survives in the presence of non-symmetric quantum fluctuations and we derive approximate analytic results to describe the quantum-to-classical crossover of this transition as a function of the saturation threshold. The described effects can be implement with various optomechanical, circuit QED or trapped ion systems, where gain and loss process at the quantum level can be engineered.

M27 **Karen Wintersperger** IMPRS-QST, LMU

Observation of parametric resonances in 1D shaken optical lattices

We study a BEC of 39K in a shaken 1D optical lattice. Due to the interplay between the external drive and interactions dynamical instabilities arise. The short-time dynamics can be captured by parametric resonances, which should lead to a fast exponential decay of the BEC. At long times, the behavior will be dominated by collision processes that slow down the decay. We observe the transition between different heating regimes and identify the onset of the parametric instabilities at short times by analysing the 2D quasimomentum distribution of the excited atoms.

M28 **Konstantin Merz** IMPRS-QST, LMU

Convergence of the density of a relativistic model of an atom on the semiclassical length scale

We consider the Chandrasekhar model of a neutral atom and give results on the convergence of the true quantum density of such an atom on the length scale $Z^{-1/3}$ away from the nucleus in the limit where the charge of the nucleus goes to infinity, keeping the ratio $\gamma = Z/c \leq 2/\pi$ fixed. We also point out how this result can be generalized to the Brown-Ravenhall model which describes atoms with nuclear charge up to $Z \approx 124.2$.

M29 **Kwangil Bae** Sogang University

Higher-moment non-local correlations from generalized correlation function

The evaluation of non-classicality in the higher-moment quantum correlation is one of considerable problems in quantum information processing. On the perspective of non-locality, possible high-order quantum correlations have been investigated based on the generalized form of correlation function. A family of high-order correlation whose construction provides the characterization of non-locality as a function of dimensionality is introduced. Also, we provide analytic approach to the characterization of the facet of the local-realistic polytope which is non-trivial in high dimensional scenario. Furthermore, a set of tight Bell inequalities inequivalent to CGLMP is derived in the low dimensions and their properties are discussed.

POSTER SESSION 2 – TUESDAY 19TH 1600-1830

T1 **Lorenzo Magrini** CoQuS, University of Vienna

Coupling of a levitated nanoparticle to a photonic crystal cavity

Achieving strong cooperativity between optical resonators and mechanical systems is the key for quantum measurements and quantum state manipulation of massive objects. Optical levitation of silica nanospheres in vacuum enables room temperature experiments due to low coupling to environment. On the other side, high optomechanical coupling is attained by exploiting the ultra-small mode volume of a photonic crystal cavity. We show precise position control of the particle in proximity of the nanofabricated cavity, allowing for optimization and characterization of the optomechanical system.

T2 **Lukas Hanschke** IMPRS-QST, TUM

Two-photon bundles from a single two-level system

We demonstrate the generation of two-photon bundles from a single two-level transition in a semiconductor quantum dot. Resonantly driven quantum two-level systems are very promising on-demand single-photon sources. Here, we show that they can surprisingly also operate in a two-photon bundling regime. Specifically, when exciting with a 2pi pulse of finite length emission of a photon may occur during the presence of the laser pulse. This is most likely when the system is in its excited state (after an area of pi has been absorbed), restarting the Rabi oscillation with a remaining area of pi and leading to a second emission.

T3 **Margret Heinze** IMPRS-QST, TUM

Controllability of Atoms in Coupled Cavities

In quantum control theory, the fundamental issue of controllability covers the question whether any two pure states can be inter-converted. Well-established criteria for controllability fail to apply to infinite-dimensional systems. One such system is the Jaynes-Cummings-Hubbard model describing atoms in coupled cavities. In this contribution, we study its controllability. For two cavities we exploit a symmetry of the system. We show that one part of the control Hamiltonians can be studied in terms of infinite-dimensional block diagonal Lie algebras while the other part breaks this symmetry. Controllability of the full system then follows by induction.

T4 **Martin Blaha** CoQuS, TU Wien

Strong coupling between nanofiber-trapped atoms and fully fiber-integrated Fabry-Perot microresonator

For building key components of optical quantum networks, such as quantum memories, an efficient interaction between light and suitable quantum emitters is required. Moreover, the latter is a prerequisite for establishing interactions between individual photons by means of an optical nonlinearity. In order to realize such an efficient light-matter interface, we plan to couple cold Cesium atoms to a fully fiber-integrated high-Q microresonator. The backbone of this experiment is a tapered optical fiber containing a sub-wavelength diameter waist. Using a two-color optical dipole trap, we interface an ensemble of laser-cooled atoms via the nanofiber waist, which is enclosed by two fiber Bragg gratings. They form a high-Q resonator for the D2 line of Cesium, while transmitting the trapping light. This scheme combines cavity enhancement and collective coupling in a single system and thus allows one to reach a very large collective light-matter coupling strength, required to implement, e.g. an inherently fiber-coupled quantum memory. Further, we aim to use the strong coupling between the atoms and the light to observe cross-phase modulation of a probe pulse by the intensity of a signal pulse. This photon-photon interaction would then be a key ingredient for optical quantum information processing.

Poster Session 2 – Tuesday 19th 1600-1830

T5 **Maximilian Lock** University of Vienna

Dynamical Casimir effect in curved spacetime

A boundary undergoing relativistic motion can create particles from quantum vacuum fluctuations in a phenomenon known as the dynamical Casimir effect. We examine the creation of particles, and more generally the transformation of quantum field states, due to boundary motion in curved spacetime. We provide a novel method enabling the calculation of the effect for a wide range of trajectories and spacetimes. We apply this to the experimental scenario used to detect the dynamical Casimir effect, now adopting the Schwarzschild metric, and find novel resonances in particle creation as a result of the spacetime curvature. We discuss a potential enhancement of the effect for the phonon field of a Bose-Einstein condensate.

T6 **Moritz Wenclawiak** CoQuS, TU Wien

The cooperative effects of confined meta-atoms

A metamaterial system built of conductively coupled dipoles is studied by THz time-domain-spectroscopy. By confining the meta-atoms in space, we find an effect comparable to classical atoms in a subwavelength volume. The rate at which the stored energy is lost is hereby substantially modified.

Poster Session 2 – Tuesday 19th 1600-1830

T7 **Nelson DarkwahOppong** IMPRS-QST, MPQ

Two-orbital interactions in ytterbium-173

Ytterbium as an alkaline-earth-like atom features a metastable excited state, the so-called clock state, that can be directly addressed from the ground state with an ultra-narrow laser. The metastable clock state opens up the possibility of probing interacting two-orbital many-body systems. We can tune the interaction strength between atoms in the ground and clock state using the recently observed inter-orbital Feshbach resonance of the isotope ytterbium-173. Since the ground and clock state have, in general, distinct atomic polarizabilities, the confinement and mobility can be tuned in state-dependent optical lattices. In our implementation, atoms in the clock state are pinned on individual lattice sites whereas ground-state atoms remain mobile. Utilizing this state-dependent mobility and the inter-orbital spin-exchange interaction of fermionic ytterbium, Kondo-like models can be realized. We spectroscopically probe the interactions of ytterbium-173 atoms in an one-dimensional state-dependent lattice.

T8 **Rachel Bruch** Weizmann Institute of Science

Maxwell's Fish-Eye-like Device for accurate wave guiding

In 1854, Maxwell provides a demonstration of an index of refraction profile which makes light-rays coming from a point focus accurately to another point. A device with such index of refraction profile, called Maxwell's Fish-Eye, could circumvent Abbe's Diffraction Limit. Having been theoretically discussed for the past decade, an experimental realization of a Fish-Eye-like device became possible, first with microwaves. Then, inspired by Maxwell's Fish-Eye, our team designed and tested an optical device whose properties allow a point-source to be refocused in a point-drain after propagation in the device.

T9 **Sebastian Huber** IMPRS-QST, LMU

Spectral function of a quantum dimer model for the pseudogap

We study a quanum dimer model, which describes several key properties of the pseudogap phase of hole-doped cuprates at low hole density p. The Hilbert space is spanned by configurations built from fermionic dimers that carry spin S = 1/2 and charge +e embedded in a resonating valence bond background of neutral bosonic spin singlet dimers. We compute the electron spectral function using exact diagonalization on a lattice of size 6x6 with twisted boundary conditions and find clear signature of the so-called pseudogap at the antinode. In a second part we show the implementation of a dynamical cluster approximation of size 2x2.

T10 **Silke Auchter** Universität Innsbruck

Characterizing background light in downconverting semiconductor waveguides

We create spectrally broadband photon pairs using parametric downconversion in semiconductor Bragg-reflection waveguides. The strong quadratic nonlinearity and the wavelength-compatibility to standard telecommunication technology makes them prime candidates for integrated photon pair sources. For any future applications, the signal-to-noise ratio (SNR) is important. Therefore, we investigate the fluorescence resulting from impurities in the semiconductor material of the waveguide using highly efficient superconducting nanowire single photon detectors. If pumped with a pulsed laser, they emit spectrally broad background light, reducing the SNR. Furthermore, we present a survey of the optical properties, like operating wavelengths, of a variety of improved samples.

T11 **Simon Weidinger** IMPRS-QST, TUM

The Loschmidt-Echo in the O(N)-model

We study the Loschmidt-Echo in the O(N)-model in quenches from the symmetry-broken to the symmetric phase. Using a large-N approximation to leading order, we explicitly write down the time evolved state and its overlap with an arbitrary symmetry-broken initial state. Then the Loschmidt-Echo is averaged over all possible initial states, we find kinks where the order parameter of a function of time crosses zero. These kinks can be understood from an effective free energy landscape for the polar angle in the average over initial states, which shows first order transitions. In the limit of large system sizes, the integral in the average can be calculated using a saddlepoint approximation and one is left with the parallel and antiparallel initial states just like in the Ising case.

T12 **Stefan Kuhn** CoQuS, University of Vienna

Rotational optomechanics with levitated nanorods

Optical control over nanomechanical structures has become a valuable tool for tests of fundamental physics and force sensing applications. We present recent experimental results on controlling the rotational degrees of freedom of optically levitated silicon nanorods. We track and manipulate their motion by exploiting the polarization of two counter-propagating, focussed laser beams. This allows us to gain full control over the rotranslational dynamics of the rod. We discuss the prospects of our levitated system for sensing applications as well as for realising rotational optomechanics and cavity cooling which may be an important step towards high-mass matter-wave interference experiments with nanoparticles.

T13 **Stefan Langenfeld** IMPRS-QST, MPQ

Memory for photonic polarization qubits with long coherence time

Many quantum communication protocols rely on the faithful storage of quantum bits. Here, we present a quantum memory based on a single 87Rb atom in a high-finesse optical resonator, capable of storing and retrieving single-photon polarization qubits with an overall efficiency of 20%. By temporarily mapping the qubit to a decoherence-protected subspace, we extend the coherence time of the memory from hundreds of microseconds to more than ten milliseconds which we further increase to more than 100 milliseconds by application of a spin-echo technique. Our results are an important milestone towards the realization of long-distance quantum communication.

T14 **Thomas Reimann** Laboratoire Kastler Brossel

Towards Normal-to-Superfluid Interfaces in Homogeneous Ultracold Fermi Gases

In most experiments with ultracold bosonic or fermionic quantum gases, the atoms are confined by using spatially inhomogeneous trap geometries. By that reason, some of the more important thermodynamic quantities, like for instance the particle density, vary as a function of position. In order to extract uniform-system properties all the same, the local density approximation as well as local probing techniques have found widespread use. However, the LDA does break down in the case of phase transitions where the correlation length diverges, and integration over a non-uniform density can potentially obscure or degrade experimental signatures. Recently, homogeneous trapping potentials have been implemented successfully in order to overcome the aforementioned limitations, both for bosons and for fermions. Here, we report on our progress towards the experimental implementation of a flat superfluid-to-normal junction in an imbalanced Fermi gas of 40 K. We are trapping the atoms in a box potential, which is divided into two homogeneous regions by an additional potential step. This step induces a phase separation between a two-spin-component superfluid and a spin-polarized normal phase. Our setup will be the starting point for the investigation of physical phenomena at the superfluid-to-normal interface, one prominent example being Andreev reflection.

T15 **Thomas Chalopin** Laboratoire Kastler Brossel

Ultracold Dysprosium gas: optical cooling and coherent dynamics of a large-spin atom

Lanthanide atoms, with their complex electronic configuration and large magnetic moment, make good candidates for the study of long-range anisotropic interactions or for the realization of artificial gauge fields. Here, we detail the behavior of our dysprosium narrow-line Magneto-Optical Trap (MOT). We show that optimal operation is reached in the spin-polarized regime, which is achieved through an interplay between gravity and optical forces. We also show that the narrow-line transition can be used to create strongly spin-dependent dipolar potentials with reduced heating, yielding to the coherent manipulation of spin states.

T16 **Thomas Stolz** MPQ

Toward a photon-photon quantum logic gate based on Rydberg interactions

The experimental realization of a photon-photon quantum logic gate based on a scheme which is not inherently probabilistic was a long-standing goal, which has been reached only recently, using a single atom in an optical resonator [1]. We pursue the same goal following a different approach in which the required strong interactions are generated by the gigantic van der Waals interaction between Rydberg atoms. A crucial ingredient needed for such a gate is an optical π phase shift generated by a single photon, which we demonstrated recently [2]. We now extended the scheme of Ref. [2] by storing an incoming photonic polarization qubit in a quantum memory consisting of an atomic ground state and a Rydberg state. We report on the implementation of this scheme in our experimental setup and quantitative studies of its performance. [1] B. Hacker et al. Nature 536, 193 (2016). [2] D. Tiarks et al. Science Advances 2, e1600036 (2016).

T17 **Thomas Kohlert** IMPRS-QST, MPQ

Observation of a Single-Particle Mobility Edge and Many-Body Localization in One-Dimensional Periodic Lattices

We present recent results on localization of ultra-cold fermions in one-dimensional quasi-periodic optical lattices. For the first time, we experimentally find a single-particle mobility edge (SPME) in a one-dimensional system, which we characterize using a combination of expansion measurements and the relaxation of local density patterns. In the corresponding interacting system we find that the dynamics is continuously slowing down as we approach a critical disorder strength, indicating that the system shows many-body localization despite the SPME. We discuss possible mechanisms which might be responsible for these observed slow dynamics.

T18 **Tuomas Jaako** CoQuS, TU Wien

Ultrastrong coupling phenomena beyond the Dicke model

We study effective light-matter interactions in a circuit QED system consisting of a single LC resonator, which is coupled symmetrically to multiple superconducting qubits. Starting from a minimal circuit model, we demonstrate that in addition to the usual collective qubit-photon coupling the resulting Hamiltonian contains direct qubit-qubit interactions, which have a drastic effect on the ground and excited state properties of such circuits in the ultrastrong coupling regime. In contrast to a superradiant phase transition expected from the standard Dicke model, we find an opposite mechanism, which at very strong interactions completely decouples the photon mode and projects the qubits into a highly entangled ground state. These findings resolve previous controversies over the existence of superradiant phases in circuit QED, but they more generally show that the physics of two- or multi-atom cavity QED settings can differ significantly from what is commonly assumed.

Poster Session 2 – Tuesday 19th 1600-1830

T19 **Uros Delic**

CoQuS, University of Vienna

Cavity optomechanics with levitated nanospheres

Although cavity cooling of levitated nanospheres has been demonstrated in recent years, regime of high 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 at low pressures. In this talk, we report on progress of combining stable optical levitation in optical tweezers with an optical cavity to reach a regime of high cooperativity at low pressures. We will present first results on optomechanical interaction with the cavity and discuss further improvements toward high cooperativity.

T20 **Valentin Goblot**

Centre for Nanoscience and Nanotechnology

Effects of Interactions in a Flat Band

We study the interplay of geometric frustration and interactions in a lattice of micropillar optical cavities exhibiting a flat energy band. The driven-dissipative nature of the system allows using resonant pumping to inject exciton polaritons directly into the non-dispersive band. At high excitation power, we observe a competition between interactions and the phase imposed by the drive, which results in non-trivial phase relations between neighboring compact localized eigenstates of the flat band.

POSTER SESSION 2 – TUESDAY 19TH 1600-1830

T21 **Valeria Saggio** CoQuS, University of Vienna

Novel Entangled Telecom-Wavelength Multi-Photon Source for Quantum Simulation Experiments

Robustness against decoherence and mobility make single photons particularly attractive for the implementation of experiments in quantum computation and quantum simulation fields. We report on the development of a novel entangled Sagnac-based six-photon source in which features such as high brightness and stability represent some of the main advantages of this type of source. Such architectures provide scalable platforms, but a strong limiting factor is the photon loss. This challenge is significantly overcome by generating photons at telecom wavelength, which provide the lowest losses in silica optics. The photon detection part relies on novel four-element superconducting nanowire detectors which exploit all the advantages coming from the latest technology, thus being able to provide high-efficiency detection in the telecom range. A multi-photon source can pave the way for quantum chemistry simulation. A quantum simulator can be pictured as a well-controlled quantum system able to imitate quantum phenomena that are intractable on classical computers because of the exponential slowdown when simulating more and more complex quantum systems. With the novel six-photon source and the high-efficiency detectors at our disposal, we go beyond the current state of the art by processing six photons into a fiber-based network to simulate the ground state of the benzene molecule.

T22 **Yijian Meng** CoQuS, TU Wien

Towards ground state cooling of atoms close to a nanofiber

We harness the strong fictitious magnetic field gradients, naturally arising in optical microtraps, to probe and manipulate the motional state nanofiber-trapped atoms. First, we take advantage of the resulting state-dependent potential to couple different motional states by the means of microwave transitions. The corresponding microwave spectra allow us to infer the trap parameters as well as the temperature of the atoms. Using a microwave sideband cooling technique, we show that the mean number of motional quanta can be reduced to about 0.3, close to the motional ground state [1]. We also show that, in a different configuration, these fictitious fields can be used to perform degenerate sideband cooling, similarly to the technique employed in optical lattices [2-3]. Remarkably, this scheme only requires a single fiber-guided optical field, which then provides three-dimensional cooling.

T23 **Yuri Minoguchi** CoQuS, TU Wien

What can Leggett-Garg Inequalities tell us about Quantum Tunneling?

Nanomechanical resonators have proven a test bed for coherent macroscopic degrees of freedom. More recently also double well potentials can be engineered either via buckling of a nanomechanical membrane or for levitated nano-spheres. In this work we theoretically address what difficulties have to be overcome to observe quantum tunnelling in a mechanical realisation of a the Caldeira-Leggett model. We argue that violations of the Leggett-Garg inequality with respect to parity measurements provides a viable witness for the presence of quantum tunnelling.

T24 **Saba ShamsLahijani** University of Vienna

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