Thursday, October 24th

Talks

Sandrine van Frank, Atominstitut TU Wien
Interferometry with non-classical motional states of a Bose-Einstein condensate

We implement an interferometric scheme with non-classical motional states of an elongated ^{87}Rb Bose-Einstein condensate. We isolate a two-level system of transverse motional states and use Optimal Control Theory methods to excite different coherent superpositions. In a previous series of experiments, we created a full population inversion to the first excited state, similar to a pi pulse on the Bloch sphere of the two-level system. In this investigation, we push this technique further and implement series of rotations on the Bloch sphere. We illustrate this concept by realizing a full Ramsey-type interferometric sequence. With this work, we illustrate the feasibility of quantum operators such as needed for any motional states interferometer.

Igor Mazets, Atominstitut TU Wien
Phonon lifetime in a one-dimensional degenerate Bose gas

We calculate the lifetime τ_k of a phonon-like quasiparticle (a phase and density wave, different from the exact excited state of the Lieb-Liniger model) with the momentum k in a 1D Bose gas by calculating the self-energy via renormalized Greens functions and obtain $\tau_k^{-1} = const(T/mn_0)^{1/2}k^{3/2}$, where m is the mass of the atom, n_0 is the 1D number density. We discuss the significance of our result for the experimentally observed dephasing of quasicondensates on atom chip as well as its relation to the problem of relaxation in integrable many-body systems.

Robin Kaiser, L'Institut Non Linéaire de Nice
Cooperative scattering of light in atomic samples: from Anderson Localization to Dicke Subradiance

The quest for Anderson localization of light is at the center of many experimental and theoretical activities. Cold atoms have emerged as interesting quantum system to study coherent transport properties of light. Initial experiments have established that dilute samples with large optical thickness allow studying weak localization of light. The goal of our research is to study coherent transport of photons in dense samples. One important aspect is the quest of Anderson localization of light with cold atoms and its relation to Dicke super- or subradiance and possibly to many body physics with long range interactions. In this talk I will give an overview on our research and present results on cooperative scattering of light by cold atoms.

Oriol Romero-Isart, IQOQI Innsbruck
Superconducting Vortex Lattices for Ultracold Atoms

In this talk I will discuss a recent proposal to use a nanoengineered vortex array in a thin-film type-II superconductor as a magnetic lattice for ultracold atoms.This proposal addresses several of the key questions in the development of atomic quantum simulators. By trapping atoms close to the surface, tools of nanofabrication and structuring of lattices on the scale of few tens of nanometers become available with a corresponding benefit in energy scales and temperature requirements. This can be combined with the possibility of magnetic single site addressing and manipulation together with a favorable scaling of superconducting surface-induced decoherence.

Marko Cetina, IQOQI Innsbruck
Measurements of Impurity Coherence in a Fermi Sea by Spin Echo

Understanding the decoherence that arises from collisions of an impurity in a Fermi sea is important for studying the transport properties of many atomic and solid-state systems. We measure the decoherence rate of a fermionic ^{40}K impurity in a Fermi sea of ^{6}Li. The interaction of the impurity with the sea can be tuned using a Feshbach resonance. For various interaction strengths, we measure the decoherence rate using the spin-echo technique. From this the collision rate of the impurity with the sea can be computed and the results show good agreement with a theory based on Fermi Liquid theory.

Posters

Nicolai Friis, IQOQI Innsbruck
Shaking Entanglement - Teleportation in Motion

We study the effects of relativistic motion on quantum teleportation and propose a realizable experiment where our results can be tested. We compute bounds on the optimal fidelity of teleportation when one of the observers undergoes nonuniform motion for a finite time. The upper bound to the optimal fidelity is degraded due to the observer's motion. However, we discuss how this degradation can be corrected. These effects are observable for experimental parameters that are within reach of cutting-edge superconducting technology. Our setup will further provide guidance for future space-based experiments.

Christoph Spengler, Institut für Theoretische Physik Innsbruck
A graph state formalism for mutually unbiased bases

A pair of orthonormal bases is called mutually unbiased if all mutual overlaps between any element of one basis with an arbitrary element of the other basis coincide. In case the dimension, d, of the considered Hilbert space is a power of a prime number, complete sets of $d+1$ mutually unbiased bases (MUBs) exist. Here, we present a novel method based on the graph state formalism to construct such sets of MUBs. We show that for n p-level systems, with p being prime number, one particular graph suffices to easily construct a set of p^n+1 MUBs. In fact, we show that a single n-dimensional vector, which is associated to this graph, can be used to generate a complete set of MUBs and demonstrate that this vector can be easily determined.

Patrick Mai, Institut für Experimentalphysik Innsbruck
Polariton scattering in coupled planar microcavities

Several theoretical studies have recently suggested that the scattering of microcavity polaritons can produce photon pairs that are entangled in either the energy or the polarization degree of freedom. One promising candidate for an efficient experimental realization of polariton entanglement schemes could be a coupled double microcavity. In this poster we will theoretically invesigate the potential of this system for entanglement generation. Furthermore we will present data on scattering experiments in a GaAs coupled cavity grown by molecular beam epitaxy. In particular we study the role of scattering by static disorder which leads to coherent resonant Rayleigh scattering.

Vedran Dunjko, IQOQI Innsbruck
Composable security of delegated quantum computation

Delegating difficult computations to remote large computation facilities, with appropriate security guarantees, is a possible solution for the ever-growing needs of personal computing power. For delegated computation protocols to be useful as a component in a larger scheme or simply to securely run two protocols in parallel the security definitions need to be composable. Here, we define composable security for delegated quantum computation. We consider protocols which provide only blindness (the computation is hidden from the server) and those that are also verifiable (the client can check that the outcome received from the server is indeed correct). We show that the composable security definition capturing both these notions can be reduced to a combination of two distinct stand-alone, non-composable, security definitions. Additionally we prove that the Broadbent, Fitzsimons and Kashefi's Universal Blind Quantum Computation protocol is composably secure.

Alexey Melnikov, IQOQI Innsbruck
Multipartite entanglement dynamics

Quantum teleportation, superdense coding and quantum cryptography are impossible without the presence of entangled subsystems. But quantum systems are always evolve in the presence of noisy environment. That is why it is important to estimate the noise level for which entanglement is still preserved. Noise can annihilate entanglement between several partitions, so we consider arbitrary partitioning of the composite system. In general, channels might not fully annihilate entanglement, but still could break entanglement between one subsystem and all other subsystems. We estimated that the detachment of a qubit from all other qubits corresponds to the case of AGE channels (annihilation of genuine entanglement). The partition of the system on two unentangled parts corresponds to EA channels (entanglement annihilating channels). Using several methods and criterions we obtain different EA and AGE channels. In the case of three qubits we estimate that the most stable against white noise state is GHZ state. We calculated the parameters of local and global depolarizing noise for which the entanglement is preserved. We studied EA and AGE channels for several multipartite states: GHZ, W and cluster states.

Walter Boyajian, Institut für Theoretische Physik Innsbruck
Compressed simulation of evolutions of the XY-model

We extend the notion of compressed quantum simulation to the XY-model. We derive a quantum circuit processing $log(n)$ qubits which simulates the 1D XY-model describing n qubits. In particular, we demonstrate how the adiabatic evolution can be realized on this exponentially smaller system and how the magnetization, which witnesses a quantum phase transition can be observed. Furthermore, we analyse several dynamical processes, like quantum quenching and finite time evolution and derive the corresponding compressed quantum circuit.

Martí Cuquet, Institut für Theoretische Physik Innsbruck
Local unitary equivalence of locally maximally entangleable states

Locally maximally entangleable states (LMES) are a class of multipartite quantum states characterized by 2^n-1 real phases, where n is the number of qubits. Prominent examples of LMES are graph states and stabilizer states. They can be prepared by applying general phase gates to a product state. One can associate any LMES to a weighted hypergraph, identifying each of these phase gates acting non-trivially on a subset of qubits to a weighted hyperedge connecting a subset of vertices. In this regard, they can be understood as a generalization of (weighted) graph states. The hypergraph, or equivalently the 2^n-1 phases, determine the entanglement. We investigated the entanglement of LME states. In particular, we discuss local unitary (LU) equivalence of these states. In some cases, LU equivalence can be reduced to the much simpler case of equivalence under the action of local Pauli gates, which simplifies the characterization of LU-equivalent classes. We show that this is the case for almost all π-LME states, and identify some relevant exceptions.

Thomas Herbst, IQOQI Wien
Entanglement swapping over a 143 km free-space link

As a direct consequence of the no-cloning theorem for quantum states, the deterministic amplification like in classical communication is impossible, which calls for more advanced techniques in a future network for cloud quantum computing. A unique solution is entanglement swapping which, together with entanglement purification and quantum storage allows to faithfully relay entanglement between adjacent nodes. While the afore mentioned building blocks of a so-called quantum repeater have been individually demonstrated in laboratory setups only, the applicability of the required technology in real world remained to be proven. Here we present a free-space entanglement-swapping experiment between the Canary Islands of La Palma and Tenerife, verifying the presence of quantum correlations between two previously independent photons separated by 143 km. We obtained a negative entanglement-witness operator, more than 6 standard deviations beyond the classical limit. By consecutive generation of the two required photon pairs and space-like separation of the relevant measurement events, we showed the feasibility of the swapping protocol in a distributed long-distance scenario, where the independence of the nodes is highly favourable. Since our results already allow for efficient implementation of entanglement purification, we anticipate our assay to be the baseline for a fully-fledged quantum repeater over a realistic high-loss and even turbulent quantum channel.

Alexander Glätzle, IQOQI Innsbruck
Frustrated Magnetism in ultra-cold Rydberg atoms and ions

We will present a discussion of quantum spin ice, which represents a paradigmatic example on how the physics of frustrated magnets is related to gauge theories. The goal is to assemble a system of cold Rydberg atoms and to design interactions that realize a toy model of quantum spin ice on a two-dimensional checkerboard lattice. In particular, we exploit the strong angular dependence of Van-der-Waals interactions between high angular momentum Rydberg states. Together with the possibility of designing step-like potentials using ground state atoms weakly dressed by Rydberg states, we can implement Abelian gauge theories in a series of geometries, which could be demonstrated within state of the art experiments. In a parallel project we implement quantum simulators for various quantum spin models and frustrated magnets using a two-dimensional triagonal crystal of ions. Utilizing state dependent trapping frequencies of ions excited to a Rybderg state we can engineer localized modes, realizing exotic plaquette interactions imposing non-local energetic constraints. This allows to access a series of interesting models: 1) the Balents-Fisher-Girvin model where topological spin liquid phase has been predicted, 2) to observe Bose metal in a Honey-comb lattice with XY interactions and 3) to provide ion-lattice implementations for U(1) lattice gauge theories.

Friday, October 25th

Talks

Christian Wuttke, Atominstitut TU Wien
Thermalization of nanofibers via thermal radiation

We study, over a large temperature range, the thermalization dynamics due to far-field heat radiation of an individual, deterministically produced silica fiber with a predetermined shape and a diameter smaller than the thermal wavelength. The temperature change of the subwavelength-diameter fiber is determined through a measurement of its optical path length in conjunction with an ab initio thermodynamic model of the fiber structure. Our results show excellent agreement with a theoretical model that considers heat radiation as a volumetric effect and that takes the emitter shape and size relative to the emission wavelength into account.

Tobias Huber, Institut für Experimentalphysik Innsbruck
Experimental test of the robustness of the non-classicality of single photons

Quantum non-classicality is not only a fundamental feature which shows the solely quantum character of an emitted photon, but is also necessary for modern applications based on the quantum character of light like quantum information processing [1]. The usual way to show that a light source is non-classical is to measure its auto-correlation [2]. In our work instead we used a different criterion developed in [3] which puts a bound on states that cannot be expressed as a mixture of coherent states. References: [1] Santori et al., Single-photon Devices and Applications (Wiley-VCH, 2010). [2] Grangier et al., Europhys. Lett. 1, 173-179 (1986). [3] Jezek et al., PRA 86, 043813 (2012).

Laurin Ostermann, Institut für Theoretische Physik Innsbruck
Protected state enhanced Quantum Metrology

Ramsey interferometry is routinely used in quantum metrology for the most sensitive measurements of optical clock frequencies. Spontaneous decay to the electromagnetic vacuum ultimately limits the interrogation time and thus sets a lower bound to the optimal frequency sensitivity. In dense ensembles of two-level systems, the presence of collective effects such as superradiance and dipole-dipole interaction tends to decrease the sensitivity even further. We show that by a redesign of the Ramsey-pulse sequence to include different rotations of individual spins that effectively fold the collective state onto a state close to the center of the Bloch sphere, partial protection from collective decoherence is possible. This allows a significant improvement in the sensitivity limit of a clock transition detection scheme over the conventional Ramsey method for interacting systems and even for noninteracting decaying atoms.

Daniel Nigg, Institut für Experimentalphysik Innsbruck
Realisation of a seven qubit error correcting code with trapped ions

Every quantum processor is affected by noise from the environment and imperfections of the gate operations. The essential method to correct for these errors and therefore enabling fault tolerant quantum computation is known as quantum error correction. Here we report on the experimental realization of a quantum error correcting code, where a logical qubit is encoded within seven ion qubits, the minimal instance of a topological stabilizer code. We demonstrate the capability of detecting arbitrary single qubit errors by measuring the full syndrome table. Additionally, we show the realization of unitary operations on the logical qubit, which is the basic requirement for fault tolerant quantum computation.

Posters

Michalis Skotiniotis, Institut für Theoretische Physik Innsbruck
Lie algebraic approach to quantum metrology

We formulate quantum metrological schemes using a Lie algebraic approach and identify the class of Hamiltonians for which it applies. This class includes, but is not limited to, almost all Hamiltonians studied in the context of quantum metrology to date. For these Hamiltonians we identify and construct a class of highly symmetric states that admit Heisenberg scaling in precision in the absence of noise, and are relatively robust against loss and dephasing noise. For the case of quantum metrology in the presence of local, commuting, phase noise we determine the states that optimize a well-known upper bound of the quantum Fisher information. These finite N-qubit states are different from spin-squeezed states, possess both permutation and collective bit-flip symmetry, and their exact quantum Fisher information, which we determine numerically, is close to that of the spin-squeezed states.

Clément Sayrin, Atominstitut TU Wien
Interaction of non-transversal light with nanofiber-trapped atoms

We have recently demonstrated a new experimental platform for trapping and optically interfacing laser-cooled cesium atoms. The scheme relies on a two-color evanescent field surrounding an optical nanofiber to localize the atoms in two diametric one-dimensional optical lattices a few hundred nanometers above the nanofiber surface. The millisecond-long ground state coherence times of the atoms and their very good coupling to fiber-guided light make this platform ideal for innovative atom/light manipulation. Here, we present an experimental study of the backreflection of light by the trapped atoms revealing the non-transversal nature of the nanofiber-guided photons. In addition, we use the resulting fictitious magnetic fields to selectively address the atoms trapped on only one side of the nanofiber. This opens the route towards atom-mediated directional channeling of light into the optical nanofiber, for which we present preliminary experimental results.

Stefan Ostermann, Institut für Theoretische Physik Innsbruck
Scattering approach to multicolor photon mediated forces and self-ordering of polarizable particles

Collective coherent scattering of laser light by polarizable point particles creates long range forces, whose properties can be tailored by choice of injected laser powers, frequencies and polarizations. We use a transfer matrix approach to study the forces induced by non-interfering pump fields of orthogonal polarization or different frequencies and find long range ordering of particles. Adjusting laser frequencies and powers then allows to tune inter-particle distances and dynamics and provides a wide range of dynamics not accessible with usual standing wave geometries. These dynamical effects should be observable in existing experimental setups with effective 1D geometries such as atoms coupled to the field of an optical nanofiber or particles in a standing wave optical lattice.

Thomas Maier, Institut für Theoretische Physik Innsbruck
Superradiant clock laser in a magic wavelength lattice

An ideal superradiant laser operating on an optical clock transition of a noninteracting ensemble of cold trapped atoms is predicted to exhibit extreme frequency stability and acurracy far below mHz linewidth. In any concrete setup a sufficiently large number of atoms have to be con- fined and optically pumped within an optical cavity e.g. by using a magic wavelength lattice to ensure uniform collective coupling to the cavity mode. Thus the atoms will also interact directly via dipole-dipole coupling and undergo collective spontaneous decay, which limits the ultimate frequency stability of the device. In the high density Dicke limit the superradiant linewidth enhancement, which is directly proportional to the atom number significantly broadens the laser line. In an alternative, more dilute, optical lattice configuration, nearest neighbor couplings will induce line shifts and fluctuations of the absolute laser frequency. We estimate the magnitude and scaling of these effects by direct numerical simulations of few atom systems for different geometries and density. Interestingly for Strontium in a regularly filled magic wavelength configuration, dipole-dipole interaction is small and collective spontaneous emission suppression can even lead to sub-radiant line narrowing in such a laser.

Oleg Gittsovich, Institut für Theoretische Physik Innsbruck
Role of correlations in the two-body marginals problem

We address the issue of deducing the global properties of correlations of tripartite quantum states based on the knowledge of their bipartite reductions, with special focus on the case of three qubits. We aim at relating the properties of the correlations in the bipartite reductions to global correlation properties. We prove that strictly classical bipartite correlations may still require global entanglement. Furthermore, we prove that separablealbeit not strictly classicalreductions may require global genuine multipartite entanglement, rather than simple entanglement. On the other hand, for three qubits, the strict classicality of the bipartite reductions rules out the need for genuine multipartite entanglement. Our work sheds new light on the relation between local and global properties of quantum states, and on the interplay between classical and quantum properties of correlations.

Bernardo Casabone, Institut für Experimentalphysik Innsbruck
Heralded entanglement of two ions in an optical cavity

In our recent experiment, we show precise control of the coupling of each of two trapped ions to the mode of an optical resonator. When both ions are coupled with near-maximum strength, we generate ion-ion entanglement heralded by the detection of two orthogonally polarized cavity photons. The entanglement fidelity with respect to the Bell state Ψ^+ reaches $F \geq (91.9 \pm 2.5)\%$ .This result represents an important step toward distributed quantum computing with cavities linking remote atom-based registers.

Katharina Schwaiger, Institut für Theoretische Physik Innsbruck
Optimal LOCC conversion of three-qubit states

Pure, truly tripartite entangled three-qubit states can be transformed into either the GHZ- or the W-state with a finite success probability. In literature local protocols are provided, which allow for such a transformation of a single copy of a quantum state with the maximum success probability, using only local operations and classical communication. We found simplified expressions of this maximum success probability via using a specific decomposition of 3-qubit states and analysed how it depends on the corresponding parameters. This also led us to the discovery of a relation between a well-known entanglement measure for three-qubit states the three-tangle and the success probability. Thus, we can indicate a physical meaning of the three-tangle for the first time.