The first joint CoQuS and IMPRS-QST Vienna

Summer School

on Complex Quantum Systems

TU Wien, Atominstitut, Vienna

18th - 22nd September 2017

Student Talks List of Abstracts

SESSION 1 – LECTURE HALL (ZD EG 01)

1705-1730 **Elisa Will** CoQuS, TU Wien

Quantum optical circulator controlled by a single chirally coupled atom

Integrated optical circuits require components that control the flow of light. Here, a particular important class are nonreciprocal devices. Recently, we realized a 4-port quantum optical circulator. For this purpose, we strongly couple a single Rb atom to a whispering-gallery-mode resonator in which photons exhibit a chiral nature: their polarization is inherently linked to their propagation direction. The chirality of the photons together with the atom exhibiting polarization-dependent transition strengths leads to a direction-dependent atom-photon interaction. As a consequence, we observe a nonreciprocal behaviour. We also show that the internal quantum state of the atom controls the operation direction of the circulator.

1735-1800 **Eleanor Crane** University College London, UK

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.

SESSION 1 – LECTURE HALL (ZD EG 01)

1805-1830 **Ralf Riedinger** CoQuS, University of Vienna

Single Phonons from a Nanomechanical Resonator

The field of optomechanics studies the interaction between light fields and mechanical resonators, coupled e.g. by radiation pressure. Recent progress in nanofabrication has allowed for those systems to enter the quantum regime. Here, we report the optical generation of single phonons, demonstrating an intensity autocorrelation function value of g(2)=0.65<1. This violation of a Cauchy-Schwarz inequality directly demonstrates the quantum nature of the mechanical oscillator, without the necessity of full state reconstruction.

SESSION 2 – SEMINAR ROOM (ZD EG 10)

1705-1730 **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.

1735-1800 **Nicola Pancotti** IMPRS-QST, MPQ

Almost Conserved Local Operators in MBL systems

Long time dynamics of non-integrable systems holds the key to fundamental questions (thermalization). Analytical tools can only apply to particular cases (integrable models, perturbative regimes). Numerical simulations, limited in time, have found evidence of different time scales. A new numerical technique for constructing slowly evolving local operators was introduced by Kim et al. in Phys. Rev. E 92, 012128 (2015). Those operators have a small commutator with the Hamiltonian and they might give rise to long time scales. In this work, we apply this technique to the many body localization problem. We show that this method can not only signal the difference between the ergodic and localized phases, but it is also sensitive to the presence of a subdiffusive phase between both.

Session 2 – Seminar Room (ZD EG 10)

1805-1830 **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. When 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.

SESSION 3 – LECTURE HALL (ZD EG 01)

1630-1700 **Matthias Zens** TU Wien

Non-Markovian quantum dynamics in the strong-coupling limit of cavity QED

Among different hybrid quantum systems, the ones based on spin ensembles coupled to superconducting microwave cavities have recently attracted much attention. I will speak about the dynamics of an ensemble of nitrogen-vacancy (NV) centers in diamond strongly coupled to a superconducting microwave resonator. We demonstrate how the decoherence induced by the inhomogeneous distribution of these NV centers can be suppressed in the strong-coupling regime - a phenomenon known as "cavity protection". More recently we could identify an even more powerful way to overcome the decoherence by spectral hole-burning and showed how this technique can be generalized to obtain a sustained revival dynamics which is interesting for quantum information processing.

1705-1730 **Antonio Rubio** IMPRS-QST, MPQ

Measuring local properties in a disordered Bose-Hubbard system

Quantum gas microscopes provide exciting perspectives to study disordered systems, since short-range-correlated disorder potentials can be generated, and microscopic observables probed with single-site resolution. In our experiments, we use such tools to prepare a two-dimensional bosonic gas in a disordered optical lattice, and measure its local properties at different regimes of disorder and tunneling. In this talk, I will discuss how these local observables could be used to identify the different phases of the disordered Bose-Hubbard model and present some recent results.

SESSION 3 – LECTURE HALL (ZD EG 01)

1735-1800 **Sebastian Scherg** IMPRS-QST, LMU

Observation of a Single-Particle Mobility Edge in a One-Dimensional Bichromatic Lattice

A single particle mobility edge (SPME) is known to occur in 3D Anderson localization, where it refers to a critical energy separating localized from extended states. Anderson localization in 1D, however, does not have a SPME, since for any finite amount of disorder, all states are localized. Here, we experimentally observe a SPME in a one-dimensional incommensurate bichromatic optical lattice by simultaneously measuring two quantities which are sensitive to (i) few localized states and (ii) few delocalized states, in good agreement with theoretical simulations. Additionally, we study the corresponding interacting system in the presence of a SPME: We find many-body localization of all states above a critical disorder strength in the fully localized single particle regime, but cannot resolve whether some many-body states already localize at a lower disorder strength.

1805-1830 **Johannes Knoerzer** IMPRS-QST, MPQ

Acoustic Traps and Lattices for Electrons in Semiconductors

We propose and analyze a solid-state platform based on surface acoustic waves (SAWs) for trapping, cooling and controlling (charged) particles, as well as the simulation of quantum many-body systems. We develop a general theoretical framework demonstrating the emergence of effective time- independent acoustic trapping potentials for particles in two- or one-dimensional structures. As our main example we discuss in detail the generation and applications of a stationary, but movable acoustic pseudo-lattice (AL) with lattice parameters that are reconfigurable in situ. We identify the relevant figures of merit, discuss potential experimental platforms for a faithful implementation of such an acoustic lattice, and provide estimates for typical system parameters. With a projected lattice spacing on the scale of $\sim$ 100nm, this approach allows for relatively large energy scales in the realization of fermionic Hubbard models, with the ultimate prospect of entering the low temperature, strong interaction regime.

SESSION 4 – SEMINAR ROOM (ZD EG 10)

1630-1700 **Flaminia Giacomini** CoQuS, University of Vienna

Quantum systems as reference frames

In all our known theories, our description of the physical world always relies on the existence of a classical, ideal reference frame. If we abandon this idealised view and consider a reference frame as a physical system, we need to take into account the dynamical degrees of freedom of the reference frame. Here we address the question of describing physics within quantum reference frames. By quantum reference frames we mean a physical system showing quantum properties such as superposition and entanglement. We describe how it is possible to change perspective from the classical external reference frame to a quantum reference frame, we show how the quantum state transforms, and we address the measurement in quantum reference frames. Moreover, we consider the dynamical laws and derive the Schrödinger equation in quantum reference frames. In particular, we analyse the situation in which the new reference frame is in a superposition of velocities from the point of view of the old one, and show that the transformation corresponding to a "superposition of Galilean boosts" preserves the covariance of the Schrödinger equation.

1705-1730 **Giulia Rubino** CoQuS, University of Vienna

Violating Bell's Inequalities to verify Indefinite Causal Orders

The study of cause-and-effect relationships is at the heart of physics and is an essential tool for a variety of research areas. In the classical realm, it is possible to reconstruct a causal relationship by studying correlations between events. Very recently a formalism for applying these techniques to quantum mechanics was developed. Astonishingly, it was then noticed that there are certain quantum processes that do not comply with any causal pattern; in fact, quantum processes may even have an undefined causal order. While there have been experimental demonstrations of processes with an undefined causal order, so far they were all based on concepts inherent to this formalism; i.e., they were theory-dependent. In my talk, I present our recent result aimed at filling that gap by performing the first theory-independent demonstration of a process with an undefined causal order. To do so, I will present a model compatible with a locally predefined causal order, and demonstrate its non-legitimacy by an experimental violation of a Bell's

Thursday 21st

Session 4 – Seminar Room (ZD EG 10)

1735-1800 **Dominic Williamson** CoQuS, University of Vienna

Symmetry-enriched topological order in tensor networks

I will describe a framework for the study of symmetry-enriched topological order using graded matrix product operator algebras. The approach is based upon an explicit construction of the extrinsic symmetry defects, which facilitates the extraction of their physical properties. This allows for a simple analysis of dual phase transitions, induced by gauging a global symmetry, and condensation of a bosonic subtheory.

1805-1830 **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.