DY 31: Quantum dynamics, decoherence and quantum information

Time: Friday 10:15–13:00 Location: MA 004

DY 31.1 Fri 10:15 MA 004

Nonexponential decoherence in a quantum Lévy kicked rotator — Henning Schomerus[1] and •Eric Lutz[2] — [1]Physics Department, Lancaster University, Lancaster, LA1 4YB, UK — [2]Institute of Physics, University of Augsburg, D-86135 Augsburg

We investigate decoherence in the quantum kicked rotator (modeling cold atoms in a pulsed optical field) subjected to noise with power-law tail waiting-time distributions of variable exponent (Lévy noise). We demonstrate the existence of a regime of nonexponential decoherence where the notion of a decoherence rate is ill defined. In this regime, dynamical localization is never fully destroyed, indicating that the dynamics of the quantum system never reaches the classical limit. We show that this leads to quantum subdiffusion of the momentum, which should be observable in an experiment.

DY 31.2 Fri 10:30 MA 004

Survival Probabilities of Coherent Energy Transfer — •Oliver Mülken — Institute of Physics, University of Freiburg, Freiburg, Germany

We consider exciton trapping in the continuous-time quantum walk framework. The survival probability displays different decay domains, related to distinct regions of the spectrum of the Hamiltonian. For linear systems and at intermediate times the decay obeys a power-law, in contrast to the corresponding exponential decay found in incoherent continuous-time random walk situations.

Reference: [1] *Phys. Rev. Lett.* **99**, 090601 (2007).

DY 31.3 Fri 10:45 MA 004

Relaxation properties of Quantum Cellular Automata — •Alexander Kettler and Günter Mahler — Universität Stuttgart, 1. Institut für Theoretische Physik, Pfaffenwaldring 57, 70550 Stuttgart

In the recent years, much research has been done on the thermodynamical behaviour of small quantum systems [1]. Amongst others there have been investigations on the relaxation into (thermal) equilibrium states and on the effect of (classical) control on the thermodynamic properties of such small quantum systems. With this in mind, we have dealt with the question of using the formalism of Quantum Cellular Automata (QCA) to control the relaxational behaviour of closed quantum systems. Here we show the effect of several different rules for two different types of QCA, applied to a 1-dimensional spin-chain and how QCA-dynamics itself can produce relaxational behaviour.

[1] J. Gemmer, M.Michel and G.Mahler: Quantum Thermodynamics, Springer 2004

DY 31.4 Fri 11:00 MA 004

Emergence of work and heat in the quantum limit — •Heiko Schröder and Günter Mahler — Universität Stuttgart, 1. Institut für Theoretische Physik, Pfaffenwaldring 57, 70550 Stuttgart

The emergence of thermodynamic properties from quantum mechanics like equilibrium, irreversibility and temperature have been under investigation for quite a while ([1] and others). Here we focus on how the concept of work (as opposed to heat) emerges from quantum mechanics even in finite quantum systems. We present a necessary and sufficient condition for pure work exchange between two (finite) quantum systems and elucidate its relation to classical control of a quantum system. Whether the concept of work is as generic in quantum sytems as it is in the classical context is discussed by means of a simple model system.

[1] J. Gemmer, M. Michel and G. Mahler: Quantum Thermodynamics, Springer 2004

DY 31.5 Fri 11:15 MA 004

Entanglement evolution after connecting quantum chains — •Viktor Eisler[1], Ingo Peschel[1], Dragi Karevski[2], and Thierry Platini[2] — [1]Freie Universität Berlin — [2]Universite Henri Poincare, Nancy

We consider quantum chains which are initially separated and in their ground states. After connecting them the quantum state evolves and the entanglement increases. It is found that the entanglement entropy displays a typical behaviour which is common for the different geometries considered. It is characterized by a rapid rise to values larger than in equilibrium followed by a slow relaxation. For critical systems the lattice results are in a very good agreement with predictions of conformal field theory.

DY 31.6 Fri 11:30 MA 004

Dephasing and the steady state in quantum many-particle systems — •Thomas Barthel and Ulrich Schollwöck — Institute for Theoretical Physics C, RWTH Aachen, D-52056 Aachen, Germany

We discuss relaxation in bosonic and fermionic many-particle systems. For integrable systems, the time-evolution from an arbitrary initial state can lead, for a given finite subsystem, to a definite steady state, determined by a certain maximum entropy density matrix. We give an explicit derivation of the steady state ensemble and devise sufficient prerequisites for the dephasing to take place. It is essential to restrict observations to a finite subsystem embedded into an (infinite) environment. We also find surprisingly simple scenarios, in which dephasing is ineffective and discuss the dependence on dimensionality and criticality. It also follows that, after a quench of system parameters, entanglement entropy will become extensive. It is thus simple to create strong entanglement for quantum computation applications, but in reduced Hilbert space simulations on classical computers, as MPS, PEPS or MERA algorithms, not possible to access arbitrarily long time scales.

DY 31.7 Fri 11:45 MA 004

Evolution of Correlation Functions in a System of Strongly Correlated Fermions after a Quantum Quench — •Salvatore R. Manmana[1], Stefan Wessel[2], Reinhard M. Noack[3], and Alejandro Muramatsu[2] — [1]Institute of Theoretical Physics (CTMC), EPF Lausanne, CH-1015 Lausanne, Switzerland — [2]Institut für Theoretische Physik III, Universität Stuttgart, Pfaffenwaldring 57/V, D-70550 Stuttgart, Germany — [3]AG Vielteilchennumerik, Fachbereich Physik, Philipps-Universität Marburg, D-35032 Marburg, Germany

We investigate the full time evolution of the density-density correlation function in a system of strongly correlated interacting spinless fermions on a one-dimensional lattice after a quantum quench, i.e., after suddenly changing the strength of the interaction between the particles [1]. Using the adaptive time-dependent density matrix renormalization group method (adaptive t-DMRG), we identify a horizon effect for specific parameters of the quench, confirming the expectation put forward by Calabrese and Cardy [2] based on conformal field theory (CFT) arguments. This effect is clearly visible when quenching into the critical regime, while it does not appear for a quench to the insulating regime.

[1] S.R. Manmana, S. Wessel, R.M. Noack, and A. Muramatsu, Phys. Rev. Lett. **98**, 210405 (2007).

[2] P. Calabrese and J. Cardy, Phys. Rev. Lett. **96**, 136801 (2006).

DY 31.8 Fri 12:00 MA 004

Decoherence properties of entangled single nuclear spins and one electron spin at room temperature in diamond — •Philipp Neumann, Torsten Gaebel, Florian Rempp, Christian Zierl, Fedor Jelezko, and Jörg Wrachtrup — 3. Physikalisches Institut, Universität Stuttgart, Germany

Generation of long-lived entanglement between single qubits is at the heart of quantum information processing. Since the coherence between single qubits in solid state systems is rather fragile one is looking for qubits with long coherence lifetimes. Those could be nuclear spins. In our case we use the electron spin of the NV-center in diamond to generate Bell States between two qubits associated with two proximal ^{13}C nuclear spins. Eventually the electron spin itself is used as a qubit and 3-particle entanglement is generated. The decoherence properties of these entangled states are investigated.

DY 31.9 Fri 12:15 MA 004

Exact dynamics in the central spin model — •Michael Bortz[1], Christian Schneider[2], Joachim Stolze[2], and Robert Stübner[2] — [1]Fachbereich Physik, TU Kaiserslautern, Germany — [2]Institut für Physik, TU Dortmund, Germany

We consider a single spin-1/2 which is coupled via inhomogeneous

Heisenberg interactions to an arbitrary number of environment spins-1/2 (central spin model). The topic of this talk is the loss of polarization of the central spin due to its exchange with the bath spins. Since the central spin model is used widely to model the decoherence of an electron spin quantum bit interacting with nuclear spins in a quantum dot, this question also is of significant experimental interest.

Our focus here is on the investigation of exact solutions of the model, both for inhomogeneous couplings and in the homogeneous limit. Using these exact solutions, we discuss the effect of tuning free parameters of the model - i.e. the initial state, the inhomogeneity of the couplings, the number of bath spins and their magnetization - on the time evolution of the central spin.

DY 31.10 Fri 12:30 MA 004

Bypassing the quantum phase transition for the Ising model in a transverse field — •Gernot Schaller — Institut für Theoretische Physik, Technische Universität Berlin

The one-dimensional quantum Ising model describes a spin-1/2 chain coupled by ferromagnetic 1d next-neighbor interactions subject to a transverse magnetic field. It is a paradigmatic example for an analytically solvable model that exhibits a second order quantum phase transition in the continuum limit from a phase with a unique ground state to a two-fold degenerate ground state with a spontaneously broken symmetry.

For a system with n spins and a merely time-dependent external magnetic field, this is reflected in a $\mathcal{O}(1/n)$-scaling of the energy gap at the critical point between ground state and first excited state. However, the situation becomes different if one considers a spatially inhomogeneous magnetic field. For a special configuration one can demonstrate analytically that the energy gap in the relevant subspace is bounded from below by a constant independent of the system size. Likewise, the ground state does not change drastically at some critical point anymore. The dynamics through this transition will be compared with the original model in the adiabatic limit.

DY 31.11 Fri 12:45 MA 004

Entanglement entropy in disordered and non-equilibrium systems — •Zoltán Zimborás[1], Viktor Eisler[2], Róbert Juhász[3], and Ferenc Iglói[3] — [1]Theoretische Physik, Univerität des Saarlandes, Campus 1, D-66041 Saarbrücken, Germany — [2]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, D-14195 Berlin, Germany — [3]Research Institute for Solid State Physics and Optics, P.O. Box 49, H-1525 Budapest, Hungary

The effects of non-equilibrium currents and quenched disorder on the entanglement properties of quantum spin chains are studied. For the investigated models, we find that the entanglement entropy of a block of spins is smaller in the ground state, than in a minimally excited non-equilibrium current-carrying pure steady state. We relate this finding to recent studies on the dynamics of entanglement entropy after a quench. For disordered models, we falsify a recent conjecture stating that the ground state entanglement entropy decreases due to disorder. We show both for aperiodically disordered couplings and for randomly disordered couplings with spatially correlation, that the ground state entanglement can either decrease and increase depending on the type of interaction and on the type of disorder.

References:
1) F. Iglói, R. Juhász, and Z. Zimborás, Europhysics Letters 79, 37001 (2007).
2) V. Eisler and Z. Zimborás, Phys. Rev. A 71, 042318 (2005).