DY 52: Quantum Dynamics, Decoherence and Quantum Information

Time: Thursday 15:00–18:15 Location: HÜL 186

DY 52.1 Thu 15:00 HÜL 186

Distributed Multipartite Entanglement Generation in Coupled Cavities — •Marc Bostelmann, Frederik Lohof, and Christopher Gies — Institute for Theoretical Physics, University of Bremen, Germany

Generation of spatially distributed entanglement is important for the realization of quantum information protocols and quantum computing. Coupled cavities offer a platform to create this kind of entanglement between spatially separated qubits [1]. By carefully tailoring excitations with external light pulses we theoretically examine the generation of entangled states, such as GHZ or Dicke states. Starting with a system of two qubits for generating bipartite entanglement, we extend the discussion to the multipartite case, exploiting symmetries of the system. Bridging the gap to experimental realizations, we study robustness of the generated entangled states to dissipation and asymmetry in the system. [1] Aron et al., PRA, 90, 062305 (2014).

DY 52.2 Thu 15:15 HÜL 186

Gaussian Approximation of the Wigner Function for the Stochastic Schrödinger Equation — •Robson Christie, Jessica Eastman, and Eva-Maria Graefe — Imperial College London, UK

Stochastic Schrödinger equations arise in many contexts in quantum mechanics, for example as an unravelling of the Lindblad equation. Here the time evolution of the Wigner function of a Gaussian state evolving along a trajectory of the stochastic Schrödinger equation for arbitrary Lindbladians is investigated in the semiclassical limit. The resulting coupled stochastic differential equations are compared to the full quantum dynamics for example systems.

DY 52.3 Thu 15:30 HÜL 186

Improving non-perturbative approximations of open-system dynamics using fermionic duality — •Valentin Bruch[1], Konstantin Nestmann[1], Maarten Wegewijs[1,2,3], Jens Schulenborg[4], and Janine Splettstoesser[5] — [1]Institute for Theory of Statistical Physics, RWTH Aachen, 52056 Aachen, Germany — [2]JARA-FIT, 52056 Aachen, Germany — [3]Peter Grünberg Institut, Forschungszentrum Jülich, 52425 Jülich, Germany — [4]Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen — [5]Department of Microtechnology and Nanoscience (MC2), Chalmers University of Technology, SE-41298 Göteborg

The evolution of a large class of fermionic open quantum systems with strong memory effects obeys an exact relation known as "fermionic duality". Given any description of the evolution of states (Schrödinger picture), it explicitly provides the corresponding description of the evolution of observables (Heisenberg picture) by a parameter substitution and some simple operations. We apply this to a non-perturbative semigroup approximation that is both completely positive and trace-preserving, as well as to its correction by a so-called "initial slip", and present a detailed comparison of these two approximations. We show that, surprisingly, the initial slip correction can be constructed for a large part using only the duality relation, circumventing further model-specific calculations. The main features of both approximations can already be seen in the exactly solvable resonant level model with strong coupling to a fermionic reservoir at finite temperature.

DY 52.4 Thu 15:45 HÜL 186

Relaxing (Quantum-) Master Equations — •Bernd Fernengel and Barbara Drossel — Institut für Festkörperphysik, Technische Universität Darmstadt, Hochschulst. 6, 64289 Darmstadt, Germany

Quantum Master Equations are special kinds of transport equations. The Gorini*Kossakowski*Sudarshan*Lindblad Equation in particular describes the time evolution of both the probabilities of, and the coherences between the quantum mechanical states.

We give several necessary and sufficient criteria for (Quantum-) Master Equations being asymptotically stable (also called *relaxing*). Instead of looking at the Lindblad Equation directly, we study a stochastic differential equation of of the ket-state vector (a so called *unravelling*) that is consistent with the Lindblad Equation. The condition for the Lindblad Equation being relaxing can then be mapped to the classical case.

DY 52.5 Thu 16:00 HÜL 186

Bose condensation of squeezed light — •Klaus Morawetz — Münster University of Applied Sciences,Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics-UFRN,Campus Universitário Lagoa nova,59078-970 Natal, Brazil

Light with an effective chemical potential and no mass is shown to possess a general phase-transition curve to Bose-Einstein condensation. This limiting density and temperature range is found by the diverging in-medium potential range of effective interaction. While usually the absorption and emission with Dye molecules is considered, here it is proposed that squeezing can create also such an effective chemical potential. The equivalence of squeezed light with a complex Bogoliubov transformation of interacting Bose system with finite lifetime is established with the help of which an effective gap is deduced. This gap phase creates a finite condensate in agreement with the general limiting density and temperature range. The phase diagram for condensation is presented due to squeezing and the appearance of two gaps is discussed. Phys. Rev. B 99 (2019) 205124

DY 52.6 Thu 16:15 HÜL 186

Coherent States for a Bosonic Atom-Molecule Conversion Systems — •Wasim Rehman[1] and Eva-Maria Graefe[2] — [1]Imperial College, London, UK — [2]Imperial College, London, UK

Coherent states are of great importance in quantum mechanics, in particular for the investigation of quantum-classical correspondence. Here I will consider a simple two-state quantum model of atom-molecule conversion in cold atom systems, where bosonic atoms can combine into diatomic molecules and vice versa. The many-particle system can be expressed in terms of the generators of a deformed SU(2) algebra. In this context the question of what the relevant coherent states are had so far not been fully addressed. Here I will present candidates for the coherent states for this system and analyse their properties and resulting phase-space structures.

15 min. break.

DY 52.7 Thu 16:45 HÜL 186

Dynamics of disordered dissipative spin-boson systems at strong coupling — Eliana Fiorelli[1,2], Pietro Rotondo[1,2], Federico Carollo[1,2], •Matteo Marcuzzi[1,2], and Igor Lesanovsky[1,2,3] — [1]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK — [2]Centre for the Mathematics and Theoretical Physics of Quantum Non-equilibrium Systems, University of Nottingham, Nottingham NG7 2RD, UK — [3]Institut fur Theoretische Physik, University of Tuebingen, Auf der Morgenstelle 14, 72076 Tuebingen, Germany

Spin-boson Hamiltonians are an effective description for numerous quantum many-body systems such as atoms coupled to cavity modes, quantum electrodynamics in circuits and trapped ion systems. While reaching strong light-matter couplings has become practicable, the understanding of the physics in this parameter regime remains a challenge. We investigate a particular example where sufficient amounts of dissipation and disorder over the local couplings make it possible to map the spin dynamics onto an effective classical master equation; the latter is, in turn, approximately governed by a fully-connected energy function, the Hopfield model, studied in the past as a simple model for an associative memory. We highlight similarities and differences in the stationary and dynamical properties of the two systems.

DY 52.8 Thu 17:00 HÜL 186

Statistics of the bifurcation in quantum measurement — Karl-Erik Eriksson and •Kristian Lindgren — Department of Space, Earth and Environment, Chalmers University of Technology, Gothenburg, Sweden

Quantum mechanics is at the basis of all modern physics and fundamental for the understanding of the world that we live in. As a general theory, quantum mechanics should apply also to the measurement process. From the general experience of non-destructive measurements, we draw conclusions about the interaction between the observed system and the measurement apparatus and how this can be described within quantum mechanics [1].

We model quantum measurement of a two-level system μ. Previous

obstacles for understanding the measurement process are removed by basing the analysis of the interaction between μ and the measurement device on quantum field theory. This formulation shows how inverse processes take part in the interaction and introduce a non-linearity, necessary for the bifurcation of quantum measurement. A statistical analysis of the ensemble of initial states of the measurement device shows how microscopic details can influence the transition to a final state. We find that initial states that are efficient in leading to a transition to a final state result in either of the expected eigenstates for μ, with ensemble averages that are identical to the probabilities of the Born rule. Thus, the proposed scheme serves as a candidate mechanism for the quantum measurement process.

[1] Eriksson & Lindgren, Entropy (2019): doi.org/10.3390/e21090834

DY 52.9 Thu 17:15 HÜL 186

The Periodical Driven, Anharmonic Oscillator — Mattes Heerwagen and •Andreas Engel — Carl von Ossietzky Universität, Oldenburg, Germany

In the thermodynamics of nanoscopic systems the correspondence between classical and quantum mechanical description is of particular importance. To scrutinize this relationship we study an anharmonic oscillator driven by a periodic external force with slowly varying amplitude both classically and within the framework of quantum mechanics. More precisely, we are interested in the energy change of the oscillator induced by the external drive. It is closely related to the distribution of work in the system. Since the amplitude $\lambda(t)$ of the external drive increase from zero to a maximum λ_{max} and than decrease back to zero initial and final Hamiltonian coincide. Our main quantity of interest is the probability density $P(E_f|E_i)$ for transitions from initial energy E_i to final energy E_f.
In the classical case non-diagonal transitions with $E_f \neq E_i$ mainly arise due to the mechanism of separatrix crossing. It is most efficiently analyzed using action-angle variables. Within the pendulum approximation analytical results for the transition probability can then be compared with numerical simulations. In the quantum case numerically exact results are complemented with analytical arguments employing Floquet techniques. The latter highlight in particular the mechanism behind the periodical variation of $P(E_f|E_i)$ with the maximal amplitude λ_{max} of the drive.

DY 52.10 Thu 17:30 HÜL 186

Extended coherently delocalized states in a frozen gas — Ghassan Abumwis, Matthew T. Eiles, and •Alexander Eisfeld — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Strasse 38, D-01187 Dresden, Germany

The long-range dipole-dipole interaction between excited states of atoms can create highly delocalized states due to the exchange of excitation between the atoms. We show that even in a random gas many of the single-exciton eigenstates are surprisingly delocalized, composed of roughly one quarter of the participating atoms. We identify two different types of eigenstates: one which stems from strongly-interacting clusters, resulting in localized states, and one which extends over large delocalized networks of atoms. These two types of states can be excited and distinguished by appropriately tuned electromagnetic pulses.

DY 52.11 Thu 17:45 HÜL 186

Relaxation dynamics in a Hubbard dimer coupled to fermionic baths — Eric Kleinherbers[1], •Nikodem Szpak[1], Jürgen König[1], and Ralf Schützhold[1,2,3] — [1]Theoretische Physik, Universität Duisburg-Essen and CENIDE, Lotharstr. 1, 47048 Duisburg — [2]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden — [3]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden

We study relaxation dynamics in a strongly-interacting two-site Fermi-Hubbard system coupled to fermionic baths. Starting with an ab initio approach, we apply several approximations leading through the real-time diagrammatics to obtain a Lindblad master equation for the dimer system itself. The latter offers a direct phenomenogical interpretation of the particle flows between the dimer and the baths. However, the approximations must be chosen and performed carefully, as for instance the local-bath approximation seems to be in contradiction with the Gibbbs final equilibrium state. In particular, at temperature zero, conserved quantities apear which lead to deceherence-free sectors. We demonstrate that the relaxation takes place in several steps on different time-scales and discuss problems related to intruduction of different approximations [1].

[1] E. Kleinherbers, N. Szpak, J. König, and R. Schützhold, arXiv: 1910:04130 (2019)

DY 52.12 Thu 18:00 HÜL 186

Spin-mapping approach for nonadiabatic molecular dynamics — •Johan E. Runeson and Jeremy O. Richardson — Laboratory of Physical Chemistry, ETH Zurich, 8093 Zurich, Switzerland

An open problem in computational physics and chemistry is to rigorously combine the quantum description of nonadiabatic processes with the simple classical trajectories of molecular dynamics (MD) simulations. Nonadiabatic processes are relevant for many modern applications, for example light harvesting in chromophores, and are characterized by the breakdown of the Born-Oppenheimer approximation.

In my talk I will show a simple way to achieve this for a general N-level quantum system in a classical environment, without invoking the surface-hopping ansatz. The key idea is to assign additional variables to each trajectory to describe the electronic states, in addition to the nuclear coordinates and momenta. These variables originate from a Wigner-like representation of the Bloch vector, that can be viewed as a classical spin. We have showed[1] how to derive a mixed quantum-classical method in this way, which shares the same equations of motion as in Ehrenfest dynamics, but differs in an important way in how initial distributions and observables are defined. This vastly improves results in benchmark systems of population dynamics compared to the conventional Ehrenfest method, without adding computational cost.

[1] J. E. Runeson and J. O. Richardson, *J. Chem. Phys.* **151**, 044119 (2019)