TT 93: Quantum Coherence and Quantum Information Systems (joint session TT/MA)

Time: Thursday 15:00–17:00 Location: H 2053

Invited Talk TT 93.1 Thu 15:00 H 2053
Non-Markovian Quantum Thermodynamics: Second Law and Fluctuation Theorems — •Robert S Whitney — Laboratoire de Physique et Modélisation des Milieux Condensés, Université Grenoble Alpes & CNRS, 25 avenue des Martyrs, BP166 38042 Grenoble, France

The thermodynamics of quantum systems which are strongly coupled to reservoirs is fraught with difficulties, such as non-factorizable initial conditions and non-Markovian system dynamics. However, there is huge practical interest in machines (heat engines, refrigerators, etc) in this strong coupling regime, because weak-coupling implies very small currents, and hence very small power outputs.

This work shows that a real-time diagrammatic technique is an equivalent of stochastic thermodynamics for strongly-coupled non-Markovian quantum machines. Symmetries are found between quantum trajectories and their time-reverses on the Keldysh contour, for any interacting quantum system coupled to ideal reservoirs of electrons, phonons or photons. These lead to quantum fluctuation theorems the same as the well-known classical ones (Jarzynski and Crooks equalities, non-equilibrium partition identity, etc), whether the system's dynamics are Markovian or not. Some of these also hold for non-factorized initial states. We identify a family of approximations, suitable for concrete calculations of a machine's power and efficiency, which respect the symmetries that ensure fluctuation theorems. In all cases, including non-factorized initial states, the second law of thermodynamics is proven to hold on average, with fluctuations violating it.
[1] arXiv:1611.00670

TT 93.2 Thu 15:30 H 2053
Nuclear spin decay in semiconductor quantum dots — •Nina Fröhling[1], Mikhail M. Glazov[2], and Frithjof B. Anders[1] — [1]Technische Universität Dortmund, Lehrstuhl für Theoretische Physik II, 44227 Dortmund — [2]A. F. Ioffe Physico-Technical Institute, 26 Politechnicheskaya, 194021 St. Petersburg, Russia

We study bath spin auto-correlation functions of nuclear spin decay in an isolated semi-conductor quantum dot doped with an electron or an electron hole as described by the central spin model. The electronic central spin is coupled to a bath of nuclear spins via hyperfine interaction, which dominates the short time regime. We study the analytical solution of the nuclear spin decay with homogeneous hyperfine coupling, as well as other limiting cases. Furthermore, we describe the nuclear spin correlation fully quantum mechanically for up to N = 18 bath spins through time evolution via the Lanczos method and discuss the influence of quadrupolar interaction and nuclear Zeeman splitting on nuclear spin decay.

TT 93.3 Thu 15:45 H 2053
Magnetic field dependency of the electron spin revival amplitude in periodically pulsed quantum dots — •Iris Kleinjohann and Frithjof Anders — Lehrstuhl für Theoretische Physik II, Technische Universität Dortmund, 44227 Dortmund

When pump-probe experiments are performed on singly charged quantum dots, the spin dynamics synchronizes with the periodic pump pulses. In experiments an external magnetic field is applied in Voigt geometry and the synchronization of spin dynamics can be observed in the electron spin polarization along the optical axis. After a pump pulse the electron spin polarization shows a complete dephasing due to the hyperfine interaction. Directly before the impact of the next pump pulse a revival of polarization occurs indicating synchronization. We describe the spin dynamics in a periodically pulsed quantum dot within the central spin model. The time evolution is calculated by a Lindblad approach and shows a revival of electron spin polarization as well as an alignment of nuclear spins. The resonance condition favors an integer or a half-integer number of electron Larmor precession over one pulse interval. The non-monotonic revival amplitude as function of the external magnetic field is related to the nuclear Zeeman term.

TT 93.4 Thu 16:00 H 2053
Semiclassical simulation of weakly coupled semiconductor quantum dots — •Andreas Fischer and Frithjof Anders — Technische Universität Dortmund, Lehrstuhl für Theoretische Physik II, 44227 Dortmund

In two-color pump-probe experiments one can excite distinct subsets of singly charged quantum dots independently by laser pulses of different photon energies. The optically oriented electron spins precess in an external magnetic field applied in Voigt geometry. Phase shifts, changing dephasing times and amplitude modulations in the signal depending on the pump configuration indicate a coherent interaction between the quantum dots. The experimental signatures can be reproduced by comprising two central spin models augmented by a Heisenberg interaction between the two central spins. The time evolution is calculated using a semiclassical approximation (SCA). To include the trion state excited by the pump pulses and the subsequent decay we combine the SCA with the quantum mechanical Lindblad equation. Our approach can be extended to multi-color pump-probe experiments.

TT 93.5 Thu 16:15 H 2053
Mode locking in a periodically pulsed quantum dot — •Natalie Jäschke and Frithjof Anders — Technische Universität Dortmund, Lehrstuhl für Theoretische Physik II, 44227 Dortmund

In pump-probe experiments single electron charged semiconductor quantum dots are subjected to periodic optical excitation generating electron and nuclear spin polarization. In the short time regime the decoherence of the electron spin polarization is governed by the hyperfine interaction with the nuclear spins. We present a theory that combines the effect of the periodic laser pump pulses and the nuclear spin bath on the electron spin polarization.

While we treat the laser pumping quantum-mechanically, a classical simulation of the Overhauser field bridges the time between two laser pulses. We analyze the time dependence of the electron spin dynamics as well as the electron spin noise spectrum. Data for the non-equilibrium steady state spectral distributions of the Overhauser field are presented for the long time limit. Using a steady state Floquet condition the peak locations of the Overhauser field distribution parallel to the external magnetic field can be derived.

TT 93.6 Thu 16:30 H 2053
Holographic Flow Equation Calculation of Entanglement Entropies of Spin Chains — •Hannes Coners and Stefan Kehrein — University of Göttingen

The Holographic Flow Equation Approach was introduced in arxiv/1703.03925 and provides a new method for quantifying entanglement of quantum many-body systems. In this talk the method will be motivated and results for different spin chains (XY, XX and Ising model) are shown. These spin chains consist of two subsystems which are coupled by a weak link (coupling strength g). To benchmark the method, different sizes of the subsystems as well as different values of g are considered.

TT 93.7 Thu 16:45 H 2053
Quantum spin systems at the edge of a quantum memory — •Yevheniia Cheipesh, Lorenzo Cevolani, and Stefan Kehrein — University of Göttingen

We consider the Kitaev Toric Code with open boundary conditions. This system has a highly degenerate ground state that lives on the boundary and can be described as a one dimensional system. The ground state is derived explicitly and its dimension scales exponentially with the size of the system. Based on this, the entanglement properties of the model are studied for two types of bipartition: the first, where the subsystem A is completely contained in B; and the second, where the boundary of the system is shared between A and B. In the former case the entanglement entropy is the same as for periodic boundary conditions, which means that the bulk is completely decoupled from the boundary on distances larger than the correlation length. In the latter, deviations from the torus configuration appear due to the edge states, and lead to the increase of the entropy. We also derive the dispersion relation of the boundary theory under the perturbation with an external magnetic field along the x-direction.