DY 15: Quantum Dynamics, Decoherence, Quantum Information

Time: Tuesday 9:30–13:15 Location: ZEU 160

DY 15.1 Tue 9:30 ZEU 160

Application of a Discrete Bessel Transform on Wave Packet Dynamics in Jacobian Coordinates — •Jan-Erik Oest and Thorsten Klüner — Institute of Chemistry, Carl von Ossietzky University Oldenburg, 26111 Oldenburg, Germany

Accurate and efficient high-dimensional wave packet dynamics is a goal that has yet to be reached, since this approach is crucial for understanding quantum mechanical phenomena and receiving state resolved expectation values. In spherical coordinates the radial part poses a difficult challenge albeit its superiority to alternative cartesian coordinates with respect to memory requirements due to reduced dimensionality in a restricted coordinate space. In the present work, we try to use the fact that Bessel functions of the first kind are radial eigenfunctions of the Laplacian as a means to construct a basis for expanding the wave function, which allows for an elegant and efficient transformation of the radial coordinate between position- and momentum-space in a Jacobian coordinate system.

This method has been implemented into our current code DYN7D, which allows for an efficient treatment of seven-dimensional quantum dynamics on surfaces, and a comparison of the performance and accuracy of this approach to conventional FFT-methods has been made. The system of particular interest is water on TiO_2 and its photocatalytic activity considering its potential for the generation of solar fuels.

DY 15.2 Tue 9:45 ZEU 160

Dissipative Floquet dynamics of a laser-driven quantum optical system — •Daniel Pagel, Andreas Alvermann, and Holger Fehske — Institut für Physik, Ernst-Moritz-Arndt-Universität, Felix-Hausdorff-Str. 6, 17489 Greifswald, Germany

A laser-driven quantum system is described by a Hamiltonian with a periodic time-dependence. In order to compute the dynamics of such a system, the simultaneous consideration of this periodicity and also of the coupling to environmental degrees of freedom is necessary. Then, the description is based on a Markovian master equation with time-dependent coefficients. To obtain a simpler differential equation with constant coefficients, the Floquet states have to be chosen as the computational basis. This procedure will be demonstrated in this talk for the example of few emitters strongly coupled to a cavity mode and driven by an external laser. As an evidence for the dynamic Stark effect, shifted peaks are observed in the emission spectra for different laser intensities. Analyzing the emission of nonclassical light with the Glauber function, we explain the additional features appearing for finite laser intensity in terms of the quasienergy spectrum of the driven emitter-cavity system. Finally, we study the generation of entanglement among two emitters, and show that the laser-excitation leads to a decrease of entanglement.

DY 15.3 Tue 10:00 ZEU 160

Reservoir engineering using Rydberg atoms — •David W. Schönleber, Christopher D. B. Bentley, and Alexander Eisfeld — Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden

We apply reservoir engineering to construct a thermal environment with controllable temperature in an ultracold atomic Rydberg system [1]. A Boltzmann distribution of the system's eigenstates is produced by optically driving a small environment of ultracold atoms, which is coupled to a photonic continuum through spontaneous emission. This technique provides a useful tool for quantum simulation of both equilibrium dynamics and dynamics coupled to a thermal environment. Additionally, we demonstrate that pure eigenstates, such as Bell states, can be prepared in the Rydberg atomic system using this method.

[1] D. W. Schönleber et al., arXiv:1611.02914 (2016)

DY 15.4 Tue 10:15 ZEU 160

Stroboscopic simulation of environmental dynamics: driven systems and full counting statistics — •Javier Cerrillo and Tobias Brandes — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

Modern non-equilibrium transport experiments provide full-counting statistics of environmental observables. We show that the effect of fast periodic driving on an open quantum system can be exploited to obtain additional environmental statistics corresponding to effective static Hamiltonians. The combination of both strategies facilitates investigation of a large portion of the environmental degrees of freedom in such form that dynamical correlations between the system and the environment can be probed. In the case of the strong-coupling, non-Markovian spin-boson model, evidence of polaron dynamics can be directly derived from the population inversion of the spin, and its role in energy transport between two baths can thus be explored. In particular, it can be put in terms of transient deviations from fluctuation-dissipation theorems associated to non-linear transport coefficients.

DY 15.5 Tue 10:30 ZEU 160

Long-lived resonances at mirrors — •Friedemann Queisser[1] and William Unruh[2] — [1]Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße, Duisburg 47048, Germany — [2]Department of Physics, University of British Columbia, Vancouver, V6T 1Z1 Canada

Motivated by realistic scattering processes of composite systems, we study the dynamics of a two-particle bound system which is scattered at a mirror [1]. We consider two different scenarios: In the first case we assume that only one particle interacts directly with the mirror whereas in the second case both particles are scattered. The coherence between the transmitted and the reflected wave-packet is reduced when the internal degree of freedom (the relative coordinate) of the bound system becomes excited. If both particles interact with the mirror, it is possible that the composite system is trapped at the mirror for a finite time. These long-lived resonances occur although the interaction of the bound system with the mirror is purely repulsive.

The findings should be of relevance for the state preparation of mesoscopic objects and for double-slit experiments with composite systems.

[1] F. Queisser and W. G. Unruh, arXiv:1503.08814

DY 15.6 Tue 10:45 ZEU 160

A control theory approach to the Schrödinger equation — •Jeanette Köppe[1], Wolfgang Paul[1], and Wilfried Grecksch[2] — [1]Institut für Physik, MLU Halle-Wittenberg, Germany — [2]Institut für Mathematik, MLU Halle-Wittenberg, Germany

Non-relativistic quantum systems are analyzed theoretically or by numerical approaches using the Schrödinger equation. Compared to the options available to treat classical mechanical systems this is limited, both in methods and in scope. However, based on Nelson's stochastic mechanics, the mathematical structure of quantum mechanics has in some aspects been developed into a form analogous to classical analytical mechanics.

We show that finding the Nash equilibrium for a stochastic optimal control problem, which is the quantum equivalent to Hamilton's principle of least action, allows to derive two things: i) the Schrödinger equation as the Hamilton- Jacobi-Bellman equation of this optimal control problem and ii) a set of quantum dynamical equations which are the generalization of Hamilton's equations of motion to the quantum world. We derive their general form for the non-stationary and the stationary case and establish a numerical procedure to solve for the ground state properties without using the Schrödinger equation. Using this method, systems without an exact known wave function, e.g. one-dimensional double-well potential, can be analyzed and an approximation to the wave function can be found.

DY 15.7 Tue 11:00 ZEU 160

Disentangling Fubini-Study geodesics in bipartite Hilbert spaces — •Kristof Harms and Stefan Kehrein — Institut für Theoretische Physik, Göttingen, Germany

In classical statistics, the Fisher information metric gives rise to a notion of distance between probability distributions which is proportional to relative entropy on an infinitesimal scale. This notion is carried over to pure quantum states, where squared probability amplitudes with respect to an observable replace classical probabilities, by the Fubini-Study metric. We study the shape of geodesics with respect to this metric between arbitrary states in pure state spaces. In particular, we show that the geodesic from an entangled state to its closest separable state in a bipartite Hilbert space entirely remains in a subspace determined by its Schmidt decomposition, where the length of the geodesic depends only on the greatest Schmidt coefficient.

15 min break

DY 15.8 Tue 11:30 ZEU 160

Driven open quantum systems and Floquet stroboscopic dynamics — •Sebastian Restrepo[1], Javier Cerrillo[1], Victor M. Bastidas[2], Dimitri Angelakis[2], and Tobias Brandes[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Centre for Quantum Technologies, National University of Singapore, 3 Science Drive 2, Singapore

We provide an analytic solution to the problem of driven open quantum systems at the high-frequency limit that goes beyond the weak coupling and Markovian assumptions. It may be applied to a large class of driven-dissipative many-body systems, since it solely relies on discrete symmetries of the system-bath Hamiltonian and provides the time evolution operator of the full Hilbert space, including bath degrees of freedom. This facilitates exploration of the effects of the driving both on the coherent part of the dynamics and also on the environment (dissipation). Due to the possibility to address strong-coupling and non-Markovian regimes, the latter may involve largely unexplored, highly complex effects. They may be interpreted in terms of the stroboscopic evolution of a continuous family of observables under the influence of an effective static Hamiltonian, which can in turn be regarded as a flexible simulation procedure of non-trivial static Hamiltonians. We instantiate the result with the study of the spin-boson model with time-dependent tunneling amplitude and provide observations of simulated polaron dynamics in the strong coupling limit.

DY 15.9 Tue 11:45 ZEU 160

An operational derivation of Jaynes' Principle — •Paul Boes, Rodrigo Gallego, Henrik Wilming, and Jens Eisert — Dahlem Center for Complex Quantum systems, Freie Universität Berlin

Jaynes principle states that a system should be assigned that state which has the largest entropy of those that are compatible with the available knowledge. Jaynes himself argued for the principle based on information theoretic least bias considerations.

Here, we prove an operational version of Jaynes' Principle: We show that there exists an equivalence relation between resource theories whose states are "macroscopic", based on partial information about a system's state, and resource theories whose states are just the corresponding maximum entropy states, in the sense that state transitions in one theory are possible iff they are possible in the other.

This equivalence arguably provides a better-suited operational justification for the application of Jaynes' Principles in a discipline like quantum thermodynamics than Jaynes' own argument.

DY 15.10 Tue 12:00 ZEU 160

High-Fidelity Hot Gates for Generic Spin-Resonator Systems — •Martin J. A. Schuetz[1], Geza Giedke[2,3], Lieven M. K. Vandersypen[4], and Ignacio Cirac[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]Donostia International Physics Center, Paseo Manuel de Lardizabal 4, E-20018 San Sebastián, Spain — [3]Ikerbasque Foundation for Science, Maria Diaz de Haro 3, E-48013 Bilbao, Spain — [4]Kavli Institute of NanoScience, TU Delft, P.O. Box 5046, 2600 GA Delft, The Netherlands

We propose and analyze a high-fidelity hot gate for generic spin-resonator systems which allows for coherent spin-spin coupling, in the presence of a thermally populated resonator mode. Our scheme is non-perturbative in the spin-resonator coupling strength, applies to a broad class of physical systems, including for example spins coupled to circuit-QED and surface acoustic wave resonators as well as nanomechanical oscillators, and can be implemented readily with state-of-the-art experimental setups. We provide and numerically verify simple expressions for the fidelity of creating maximally entangled states under realistic conditions.

DY 15.11 Tue 12:15 ZEU 160

Quantum simulation with acoustic lattices — •Johannes Knörzer[1], Martin Schuetz[1,2], Eric Kessler[2], Geza Giedke[1,3], Lieven Vandersypen[4], Mikhail Lukin[2] und Juan Ignacio Cirac[1] — [1]Max-Planck-Institut für Quantenoptik, Garching, Deutschland — [2]Harvard University, Cambridge, USA — [3]DIPC, San Sebastian, Spanien — [4]TU Delft, Delft, Niederlande

We propose and analyze a solid-state platform for quantum simulation based on high-frequency surface acoustic waves (SAWs). We develop a general theoretical framework demonstrating the emergence of an effective time-independent acoustic lattice for charge carriers in two-dimensional quantum wells and one-dimensional wires; with lattice parameters that are reconfigurable in real time. We 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 100nm, this approach allows for relatively large energy scales in the realization of the fermionic Hubbard model, with the ultimate goal to enter regimes where the antiferromagnetic spin-spin interaction strength exceeds cryostatic temperatures. Implementation and read-out schemes are discussed.

DY 15.12 Tue 12:30 ZEU 160

Understanding errors in digital quantum simulation of fermionic systems — •Jan-Michael Reiner, Sebastian Zanker, Iris Schwenk, Juha Leppäkangas, and Michael Marthaler — Institut für Theoretische Festörperphysik, Karlsruhe Institute of Technology (KIT)

The simulation of complex fermionic systems is one of the most anticipated applications of quantum computing. Various properties of such systems can be described by time-dependent correlation functions of two fermionic operators. Fermions can be mapped onto qubits, e.g., via the Jordan-Wigner transformation. We discuss how (anti-)time sorted correlation functions can be measured in the qubit system. Deploying Keldish formalism, we investigate the effects of relaxation, and dephasing of the qubits, as well as gate errors in an quantum algorithm using the Trotter expansion. We analyze how this translates to a simulated fermionic system, allowing for qualitative understanding of errors of a quantum simulation.

DY 15.13 Tue 12:45 ZEU 160

Untersuchung der Stabilität von Quantendynamiken — •Lars Knipschild und Jochen Gemmer — Universität Osnabrück, Deutschland

Viele Prozesse im Bereich der linearen Nichtgleichgewichtsthermodynamik können in Form von Mastergleichungen oder Fokker-Plank-Gleichungen formuliert werden. Beispiele sind neben zahlreichen alltäglichen Prozessen auch Ausgleichsprozesse der Magnetisierung oder der Energie in abgeschlossenen Spinsystemen mittlerer Größe (16-32 Spins). Um zu untersuchen, wieso diese Art der Beschreibung auch in abgeschlossenen Quantensystemen häufig gute Resultate liefert, werden verschiedene Testsysteme (Hamiltonians) so generiert, dass der Erwartungswert einer Observablen dem Verlauf ausgewählter Referenzdynamiken entspricht. Unter diesen befinden sich Dynamiken, die nicht durch einen stochastischen Prozess beschreibbar sind. Es wird untersucht, wie sich zufällige Störungen auf die verschiedenen Dynamiken auswirken und ob sich qualitative Unterschiede in der Stabilität der Testsysteme zeigen.

DY 15.14 Tue 13:00 ZEU 160

Topological pumping of photons in nonlinear resonator arrays — Jirawat Tangpanitanon[1], •Victor Manuel Bastidas[1], Sarah Al-Assam[2], Pedram Roushan[3], Dieter Jaksch[2,1], and Dimitris G. Angelakis[1,4] — [1]Centre for Quantum Technologies, National University of Singapore, 3 Science Drive 2, Singapore 117543 — [2]Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, United Kingdom — [3]Google Inc., Santa Barbara, California 93117, USA — [4]School of Electrical and Computer Engineering, Technical University of Crete, Chania, Crete, Greece, 73100

We show how to implement topological or Thouless pumping of interacting photons in one dimensional nonlinear resonator arrays, by simply modulating the frequency of the resonators periodically in space and time[1]. The interplay between interactions and the adiabatic modulations enables robust transport of Fock states with few photons per site. We analyze the transport mechanism via an effective analytic model and study its topological properties and its protection to noise. We conclude by a detailed study of an implementation with existing circuit QED architectures.

[1] J. Tangpanitanon, V. M. Bastidas, S. Al-Assam, P. Roushan, D. Jaksch, and D. G. Angelakis, Phys. Rev. Lett **117**, 213603 (2016)