DY 43: Poster: Quantum Dynamics and Many-Body Systems

Time: Thursday 13:00–16:00 Location: P1

DY 43.1 Thu 13:00 P1

applications of generalized coherent states in bosonic systems — •yulong qiao[1], Frank Grossman[2], and Joonsuk Huh[3] — [1]Institute for theoretical physics, TU Dresden, 01062 Dresden, Germany — [2]Institute for theoretical physics, TU Dresden, 01062 Dresden, Germany — [3]Department of Chemistry, Sungkyunkwan University, Suwon 16419, Republic of Korea

Generalized coherent states (GCS) are found to be very useful for studying bosonic systems with a fixed number of particles, such as the Bose-Hubbard model and boson sampling. Firstly, we present the non-equilibrium dynamics of the Bose-Hubbard model based on the time-dependent variational principle [1]. Increasing the multiplicity of GCS leads to converged results quickly for weak interaction strength, which indicates that GCS are a well-suited basis in the superfuild phase. Secondly, we investigate the boson sampling problem whose input state is a Fock state. Using an exact expansion of the Fock state in terms of GCS, we obtain the output state by means of a unitary rotation. By this process the total information is contained in a finite number of GCS. The specific structure of the GCS allows us to split the whole system into two parts easily and to study the entanglement entropy of the output state in detail [2].

[1] Y. Qiao and F. Grossmann, Exact variational dynamics of the multimode Bose-Hubbard model based on SU(M) coherent states, Phys. Rev. A 103, 042209 (2021).

[2] Y. Qiao, J. Huh, F. Grossmann, Entanglement in the full state vector of boson sampling, arXiv:2210.09915 [quant- ph] (2022).

DY 43.2 Thu 13:00 P1

Coupling in Optical Microcavity-Arrays — •Tom Rodemund and Martina Hentschel — Department of Physics, University of Applied Sciences Chemnitz, Chemnitz, Germany

Optical microcavities capture light by total internal reflection in so-called whispering-gallery modes. Deformed disk-shaped microcavities, for example of Limaçon shape, allow one to keep high Q-factors while manipulating the far-field emission via the resonator geometry, thereby allowing for a wide range of applications from microlasers to sensors.

Coupling of several microdisk resonators enhances the possibilities to tame light considerably [1]. Depending on the number and distance of the coupled cavities, the far-field characteristics vary tremendously and can even be reversed [1]. Here, we investigate the underlying mechanisms. To this end we use phase-space methods and analyze the resonance wave functions in real space as well as the corresponding Husimi functions to characterize the coupling behavior. We employ ideas from ray-wave correspondence to deepen our insight by establishing a relation to the nonlinear light ray dynamics and its fingerprint in the Poincaré surface of section.

[1] J. Kreismann et al., Phys. Rev. Res. 1, 033171 (2019).

DY 43.3 Thu 13:00 P1

From Dual Unitarity to Generic Quantum Operator Spreading — •Michael A. Rampp, Roderich Moessner, and Pieter W. Claeys — Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany

Dual-unitary circuits are paradigmatic examples of exactly solvable yet chaotic quantum many-body systems, but solvability naturally goes along with a degree of non-generic behaviour. By investigating the effect of weakly broken dual-unitarity on the spreading of local operators we study whether, and how, small deviations from dual-unitarity recover fully generic many-body dynamics. We present a discrete path-integral formula for the out-of-time-order correlator and use it to recover a butterfly velocity smaller than the light-cone velocity, $v_B < v_{LC}$, and a diffusively broadening operator front, two generic features of ergodic quantum spin chains absent in dual-unitary circuit dynamics. We find that the butterfly velocity and diffusion constant are determined by a small set of microscopic quantities and that the operator entanglement of the gates plays a crucial role.

DY 43.4 Thu 13:00 P1

Transmission of a single electron through a Berry ring — •Kenmoe Maseim Bassis — Universitätsstraße 31, 93053, Regensburg — Prüfeningerstraße 121, 93049, Regensburg

A theoretical model of transmission and reflection of an electron with spin is proposed for a mesoscopic ring with rotating localized magnetic moment. This model may be realized in a pair of domain walls connecting two ferromagnetic domains with opposite magnetization. If the localized magnetic moment and the traveling spin is ferromagnetically coupled and if the localized moment rotates with opposite chirality in the double path, our system is formulated in the model of an emergent spin-orbit interaction in a ring. The scattering problem for the transmission spectrum of the traveling spin is solved both in a single-path and a double-path model. In the double path, the quantum-path interference changes dramatically the transmission spectrum due to the effect of the Berry phase. Specifically, the spin-flip transmission and reflection are both strictly forbidden.

DY 43.5 Thu 13:00 P1

Optimal route to quantum chaos in the Bose-Hubbard model — Lukas Pausch[1,2], Edoardo Carnio[2,3], Andreas Buchleitner[2,3], and •Alberto Rodríguez[4] — [1]Département de Physique, Université de Liège, Belgium — [2]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104, Freiburg, Germany — [3]EUCOR Centre for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany — [4]Departamento de Física Fundamental, Universidad de Salamanca, E-37008 Salamanca, Spain

The dependence of the chaotic phase of the Bose-Hubbard Hamiltonian [1,2] on particle number N, system size L and particle density is investigated in terms of spectral and eigenstate features. We analyze the development of the chaotic phase as the limit of infinite Hilbert space dimension is approached along different directions, and show that the fastest route to chaos is the path at fixed density $n \lesssim 1$ [3]. The limit $N \to \infty$ at constant L leads to a slower convergence of the chaotic phase towards the random matrix theory benchmarks. In this case, from the distribution of the eigenstate generalized fractal dimensions, the ergodic phase becomes more distinguishable from random matrix theory for larger N, in a similar way as along trajectories at fixed density.

[1] L. Pausch *et al.*, Phys. Rev. Lett. 126, 150601 (2021)
[2] L. Pausch *et al.*, New J. Phys. 23, 123036 (2021)
[3] L. Pausch *et al.*, J. Phys. A 55, 324002 (2022)

DY 43.6 Thu 13:00 P1

Chaotic resonance modes in optical microcavities — •Florian Lorenz and Roland Ketzmerick — TU Dresden, Institut für Theoretische Physik, Dresden, Germany

Following a recently proposed conjecture, we show that resonance modes in dielectric cavities are a product of a conditionally invariant measure from classical dynamics and universal fluctuations [1]. The first factor describes the average of modes with similar lifetime and has a multifractal structure which we resolve on very fine scales. It is approximately described by conditionally invariant measures from classical dynamics [1]. However, increasing the openness of a dielectric cavity (i.e. by investigating TE modes or a small refractive index) is a challenge to the construction of appropriate classical measures.

[1] R. Ketzmerick, K. Clauß, F. Fritzsch, and A. Bäcker, Chaotic resonance modes in dielectric cavities: Product of conditionally invariant measure and universal fluctuations, Phys. Rev. Lett. **129**, 193901 (2022).

DY 43.7 Thu 13:00 P1

Classical and quantum escape dynamics in the vicinity of hyperbolic fixed points — •Alexander Hempel, Jonas Stöber, and Arnd Bäcker — TU Dresden, Institut für Theoretische Physik, Dresden, Germany

For an ensemble of orbits started in the vicinity of an inverse hyperbolic fixed point in the area-preserving standard map we find a slow, non-exponential decay of the survival probability. It turns out that this is governed by the geometry of the stable and unstable manifolds which form a partial barrier enclosing a resonance zone. An analysis of transit times through the resonance zone using the lobe dynamics of the partial barrier, including re-entrance of orbits, explains the non-exponential decay. Quantum mechanically, coherent states follow the classical behavior for remarkably long times.

DY 43.8 Thu 13:00 P1

Many-body localization in disordered Heisenberg-type spin chain models — •Yilun Gao and Rudolf A. Römer — Department of Physics, University of Warwick, Coventry, CV4 7AL, UK

Disordered quantum systems have become an important research topic in modern condensed matter physics ever since the discovery of Anderson localization. The investigation of many-body localization in quantum interacting systems has received much recent attention following the increase of computational power and improvement in numerical methods. One of the standard models that has been studied is the disordered spin-1/2 Heisenberg chain. It was shown that there exists a phase transition from ergodic states to many-body localized states as the disorder is increased. Here, we focus on a variant of the model where the exchange couplings between neighboring spins are taken to be disordered. We calculate the consecutive-spectral-gap ratio and its probability distribution for different system sizes and disorders. The result is compared with the case when the disorder is onsite. We average over many disorder realizations. We also plot the sample-to-sample variance against disorder and system size as a further characteristic of the phases across the MBL transition.

DY 43.9 Thu 13:00 P1

Nonlinear magnetoelectric effects in class AIII 3D topological insulators — •Nithin Thomas, Jan Wilhlem, and Ferdinand Evers — Institute of Theoretical Physics, Regensburg University, D-93053 Regensburg, Germany

We investigate nonlinear magnetoelectric effects in class AIII 3D topological insulators[1]. Within the framework of a tight-binding model, we numerically observe a quadratic scaling of wrapping currents with the electric field strength. Starting with the theory of nonlinear Hall effect induced by Berry curvature dipole[2], we develop an analytic description of our numerical findings.

Shinsei Ryu et al 2010 New J. Phys. 12 065010 (2010) Inti Sodemann and Liang Fu, Phys. Rev. Lett. 115, 216806 (2015)

DY 43.10 Thu 13:00 P1

Flat band physics for dispersive bands — •Jie Liu[1], Carlo Danieli[2], and Rudolf A. Römer[3] — [1]School of Physics and Optoelectronics, Xiangtan University, Xiangtan 411105, China — [2]Department of Physics, University of Sapienza, Piazzale Aldo Moro 5, 00185 Rome, Italy — [3]Department of Physics, University of Warwick, Coventry, CV4 7AL, United Kingdom

Lieb models provide a convenient test bed for the characterization of compactly localized states (CLS) in "flat" energy bands. The CLS have been discussed as potential candidates for information storage applications. However, they are typically sensitive to perturbations. Uncorrelated onsite disorder in most cases lifts the existence of CLS irrespective of the disorder strength and induces wave localization in flat band lattices. In certain cases, however, local symmetries within flat band lattices suggest local correlations in the onsite disorder which result in anomalous localization features. Here we make use of these ideas to proposed an engineered “disorder” that allows to keep the compactness of the CLS while it at the same time changes half of the dispersive states to become more CLS-like. The work has potential applications for the many situations where flat-band physics has been shown to be relevant, effectively stabilizing the CLS.

DY 43.11 Thu 13:00 P1

Electron cavity optics in bilayer graphene billiards — •Lukas Seemann[1], Angelika Knothe[2], Klaus Richter[2], and Martina Hentschel[1] — [1]Technische Universität Chemnitz, D-09107 Chemnitz, Germany — [2]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

Rapid developments in the field of 2D materials and their nanostructures make it possible to trap charge carriers with different dispersions in various confinement geometries with a high degree of control. This progress now allows studying 2D electron optics phenomena enriched by the charge carriers' different electronic and topological properties compared to the photonic. Here, we demonstrate the differences induced by deviating from an isotropic dispersion relation by theoretically investigating cavities in gapped bilayer graphene characterized by the presence of a trigonally warped band structure [1]. We employ an approach based on ray-wave correspondence [2] and find dramatic deviations from the optical-case behavior with clear signatures in phase space. We show that the fermion optics characteristics can be conveniently tuned by gate voltages and illustrate the experimentally relevant consequences.

[1] C. Gold, A. Knothe, A. Kurzmann, A. Garcia-Ruiz, K. Watanabe, T. Taniguchi, V. Fal'ko, K. Ensslin, T. Ihn, Phys. Rev. Lett. 127, 046801 (2021).

[2] J.-K. Schrepfer, S. Chen, M.-H. Liu, K. Richter, and M. Hentschel, Phys. Rev. B 104, 155436 (2021).

DY 43.12 Thu 13:00 P1

Quantum many-body dynamics in two dimensions using tree tensor networks — •Wladislaw Krinitsin[1], Niklas Tausendpfund[1,2], Matteo Rizzi[1,2], and Markus Schmitt[1] — [1]Forschungszentrum, Jülich, Deutschland — [2]Institut der Theoretischen Physik, Köln, Deutschland

Many body systems out of equilibrium are notoriously difficult to solve due to the rapid growth of entanglement with time. In particular the rapidly expanding possibilities to address 2-dimensional systems in quantum simulation turn a spotlight on the lack of reliable numerical methods in this regime. We explore an approach to solve the time dependence of 2-dimensional systems by applying the time-dependent variational principle (TDVP) to Tree Tensor Networks (TTNs). More specifically, this method is used to study non-ergodic dynamics in the quantum Ising model.

DY 43.13 Thu 13:00 P1

Numeric investigation of the Kibble-Zurek mechanism in 2D — •Seyedeh Parya Katoorani[1], Ralf Schützhold[2], Naser Ahmadiniaz[3], Gernot Schaller[4], and Friedemann Queisser[5] — [1]Theoretical Physics(FWZ),HZDR,Dresden,Germany, — [2]Theoretical Physics(FWZ),HZDR,Dresden,Germany — [3]Theoretical Physics(FWZ),HZDR,Dresden,Germany — [4]Theoretical Physics(FWZ),HZDR,Dresden,Germany — [5]Theoretical Physics(FWZ),HZDR

The two-dimensional classical Ising model can be approximately implemented on a Si(100) surface, where the dimers are anisotropically coupled. In particular, the setup allows for time-dependent temperatures, where the Kibble-Zurek mechanism predicts topological defect formation while traversing the critical point at a finite rate. We numerically investigate the corresponding relaxation dynamics of a two-dimensional extended Ising model with diagonal couplings and time-dependent temperature.

DY 43.14 Thu 13:00 P1

Explicit expressions for stationary states of the Lindblad equation for a finite state space — •Bernd Michael Fernengel — TU Darmstadt, Darmstadt, Germany

The Gorini-Kossakowski-Sudarshan-Lindblad Equation is a quantum master equation describing the time evolution of quantum mechanical states. It is used to model open quantum systems. We give explicit expressions of stationary solutions of the Lindblad equation in the case of a finite state space, using the concept of state transition networks of Markov chains. Our treatment is based on the so-called quantum-jump unravelling, which is an ensembles of stochastic quantum trajectories, compatible with the Lindblad equation. A single such trajectory is a piecewise deterministic process, which is interrupted by stochastic jumps. We discuss differences to the classical case and conditions, under which the Lindblad equation is asymptotically stable.

DY 43.15 Thu 13:00 P1

Generic partial barriers to chaotic transport in 4D symplectic maps — •Benjamin Hertzsch, Arnd Bäcker, and Roland Ketzmerick — TU Dresden, Institut für Theoretische Physik, Dresden, Germany

Chaotic transport in Hamiltonian systems is often restricted due to the presence of partial barriers, leading to a limited flux between different regions in phase phase. Typically, the most restrictive partial barrier in a 2D symplectic map is based on a cantorus, the Cantor set remnants of a broken 1D torus. Recently, for a weakly coupled 4D symplectic map, a partial barrier based on a normally hyperbolic invariant manifold with the structure of a cantorus has been established. We investigate how this can be extended to a generic 4D map, where the most restrictive partial barriers are expected to lie on the most irrational slopes between resonance channels in frequency space.

DY 43.16 Thu 13:00 P1

Stability analysis of a periodically driven ultra-cold Bose gas — •Larissa Schwarz, Simon B. Jäger, Dimo Claude, Imke Schneider, and Sebastian Eggert — Physics Department and Re-

search Center OPTIMAS, Technische Universität Kaiserslautern, D-67663, Kaiserslautern, Germany

We theoretically study the dynamics of a Bose-Einstein condensate under periodic driving of the s-wave scattering length. In this setup, we first determine the stability of the condensate using Bogoliubov theory with time-periodic modulation. We find an exponential gain in the resonant k-modes due to a parameteric amplification which leads to a rapid condensate depletion. These findings are compared with the simulation of the Gross-Pitaevskii equation which shows the formation of a density-wave pattern with the predicted k-wavevector. We extend the Bogoliubov theory by including non-linearities which result in an effective damping of the k-modes. This enables the creation of stable density-wave pattern below a critical driving strength. Moreover, above this critical driving strength we analyze simple non-quadratic models and find macroscopic and stable occupation of the resonant k-mode.

DY 43.17 Thu 13:00 P1

Energy-conserving adaptive partitioning QM/MM simulations — •Marvin Nyenhuis[1,2] and Nikos Doltsinis[1,2] — [1]Institute for Solid State Theory, University of Münster, Wilhelm-Klemm-Straße 10, 48149 Münster, Germany — [2]Center for Multiscale Theory and Computation,, University of Münster, Wilhelm-Klemm-Straße 10, 48149 Münster, Germany

Bachmann and Doltsinis have recently proposed an energy-conserving adaptive partitioning method between two different atomistic representations based on an extended Hamiltonian, which switches the system from a potential energy surface V_1 to another potential V_2. In this work, we develop this method further and implement it into the QM/MM molecular dynamics framework of the CP2K software package, enabling atoms travelling out of (or into) the QM region to adopt an MM (or QM) representation. For a test system consisting of a solvated sodium ion, we analyse the degree to which energy is conserved over a large number of switching events depending on the value chosen for the mass of the fictitious lambda particle. In addition, we investigate how this choice affects the switching speed and we seek the optimum mass that simultaneously ensures rapid switching and good energy conservation.

DY 43.18 Thu 13:00 P1

Classification of noisy spectra using machine learning — Aritra Mishra and •Alexander Eisfeld — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

A general problem in quantum mechanics is to obtain information of the eigenstates from the experimentally measured data which consists inherent noises. For an example, in the case of molecular aggregates, the information about excitonic eigenstates is vitally important to understand their optical and transport properties [1,2].

We show that it is possible to reconstruct the underlying delocalised aggregate eigenfunctions from near-field spectra using convolution neural networks [3]. We also investigate convolution neural networks for an eigenstate based classification of the spectra, in the presence of noise. Each aggregate eigenstate, corresponds to a distinctly looking spectrum. Therefore, we can assign a class to each of the eigenstate. We find that the network is also able to classify the spectra of different noise strengths along with the one it has been trained for.

[1] X. Gao and A. Eisfeld, J. Phys. Chem. Lett. 9, 6003 (2018)
[2] S. Nayak, F. Zheng and A. Eisfeld, J. Chem. Phys. 155, 134701 (2021)
[3] F. Zheng, X. Gao and A. Eisfeld, Phys. Rev. Lett. 123, 163202 (2019)

DY 43.19 Thu 13:00 P1

Exact time local equations of quantum dissipation with minimal state space — •Meng Xu[1], Vasilii Vadimov[2], Malte Krug[1], Jürgen T. Stockburger[1], and Joachim Ankerhold[1] — [1]Institute for Complex Quantum Systems and IQST, Ulm University — [2]QCD Labs, QTF Centre of Excellence, Aalto University, Finland

We present a minimal state space approach to unravel the Feynman path integral influence functional for open quantum system dynamics. The resulting time local evolution equation for the density in minimally extended state space is exact and in combination with tensor network methods, can be very efficiently propagated with very high precision also for long times [1]. It is capable to treat the full non-Markovian dynamics, regardless of low temperature, structured reservoir, and strong system-bath coupling. On a formal level, its intriguing structure allows to demonstrate that the new equation is closely related to an entire family of representations (Lindblad-type, Fokker-Planck-type). Alternative perturbative and non-perturbative formulations of quantum dissipation can be derived from it, with our new approach being favorable through a comparably low dimension of auxiliary dimensions. With the new platform at hand, lab-based high-precision simulations in parallel to actual experiments with, for example, superconducting qubits are within reach.

[1] M. Xu *et al.*, Phys. Rev. Lett. **129**, 230601 (2022).

DY 43.20 Thu 13:00 P1

Training Restricted Boltzmann Machines for Spin-1 Quantum Magnets — •Abhiroop Lahiri and Michele Casula — IMPMC, Sorbonne Université, Paris, France

Neural Network Quantum states (NQS) have gained popularity in recent times for their ability to study quantum many-body systems. Restricted Boltzmann Machines (RBMs) have been quite successful in providing an accurate representation of the ground states of spin-1/2 quantum systems both in one and two dimensions. Based on recent studies of the spin-1 representation of RBMs using one-hot encoding and a quadratic energy function, we aim to test these ansatze for spin-1 models in various configurations. We train the network parameters and investigate their behaviour to resolve the ground state of these systems.

DY 43.21 Thu 13:00 P1

Enhancement and suppression of charge transport in organic semiconductors under strong light-matter coupling — •Sebastian Stumper and Junichi Okamoto — University of Freiburg, Institute of Physics

We study a model of an organic semiconductor coupled to a cavity with variable disorder and electronic filling factors as well as dissipative effects. It represents a fermionic generalization of the Dicke model such that charges can move between lattice sites.

Different mechanisms are explored to explain experimentally observed conductivity enhancements in the strong coupling regime. These are either based on an increase of the charge mobility or of the charge density. Mobilities and the generalized inverse participation ratio, which characterizes localization, are accessible from various two- and four-point correlators that we obtain by a Lanczos technique. In agreement with several previous studies, we find that excitons are indeed delocalized under strong light-matter coupling and show an enormously increased mobility. The same is not true for electrons and holes.

Charge densities are increased by excitation of electrons to the upper band through counter-rotating light-matter interaction terms. However, this is counteracted by the cavity-mediated formation of bound electron-hole states. We analyze the relative strengths of these processes under finite size scaling, and how the formation of bound states is affected by disorder and dephasing. In certain limits for an undoped system, the Dicke model is recovered.

DY 43.22 Thu 13:00 P1

Investigation of two-dimensional quantum billiards with mixed dynamics in microwave resonators — •Lennart Anderson and Andreas Wieck — Angewandte Festkörperphysik, Ruhr-Universität Bochum

Based on the analogy of the stationary Schrödinger equation and the Helmholtz equation for a flat electromagnetic resonator, two-dimensional quantum mushroom billiards are studied in the microwave regime. We give a practical approach, ranging from the construction process of the resonator to the eigenvalue statistics. I.e. the frequency spectrum is measured for different stem widths. The obtained nearest neighbour spacings are fitted with respect to three different distribution functions for systems with mixed dynamics respectively. The degrees of chaoticity are determined analytically, dependent on the stem width, and compared with the fitted data. The presented approach is of both conceptual and educational interest.