DY 69: Poster: Quantum Systems

Time: Thursday 15:30–18:00 Location: Poster A

DY 69.1 Thu 15:30 Poster A

Nonequilibrium dynamics of laser-excited graphene: ab-initio MD simulations including electron-phonon coupling — •Sergej Krylow and Martin E. Garcia — Universität Kassel, Theoretische Physik II

Graphene attracted a lot of interest in the last decade due to its unique physical properties. Despite intensive research, there are still open questions regarding the response of Graphene to ultrashort laser pulses. In ultrafast electron diffraction experiments, a decay of Bragg peak intensities with two different decay times can be observed. The generation of a few optical phonons, so called SCOPs, which are strongly coupled to the electronic subsystem is believed to play a major role for this effect. However, the origin of the two timescales and the involved dynamics are not fully understood yet. To address this problem, we performed ab-initio molecular dynamic simulations of monolayer graphene immediately after laser excitation. Our results show that the short decay time can be accounted by the generation of the SCOPs and the long decay time to the equilibration of the phonon system. Furthermore, we see two stages in the dynamics of the lattice towards thermal equilibrium. Within the first picosecond after laser excitation mainly high- and mid-frequency phonons are created. Then, on a much longer timescale, the equilibration with low-frequency phonons occurs. Our result clearly suggest that the bottleneck for thermal equilibration in monolayer graphene are the low-frequency phonons.

DY 69.2 Thu 15:30 Poster A

Quantum non-Markovianity: Simulation, Quantification and Thermodynamics — •Philipp Strasberg — Complex Systems and Statistical Mechanics, Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg, Luxembourg

This poster reviews recent progress in the understanding of non-Markovian open quantum systems from the author's perspective. Markovian embedding strategies, which allow for a convenient treatment of non-Markovian open quantum systems, are reviewed. Their thermodynamic interpretation and potential to understand more realistic heat engines are discussed. Finally, also some easily computable witnesses of non-Markovianity are presented.

DY 69.3 Thu 15:30 Poster A

Multifractal properties of the ground state of the Bose-Hubbard model — Jakob Lindinger, Andreas Buchleitner, and •Alberto Rodríguez — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Staße 3, D-79104 Freiburg, Germany

We study the multifractal properties of the ground state of the one-dimensional Bose-Hubbard model in Fock space. We confirm that the limit of vanishing interaction exhibits non-trivial multifractality in the Fock basis [1]. In order to get access to the multifractal properties at arbitrary values of the interaction strength, we use exact diagonalisation and quantum Monte Carlo simulations (which enable us to reach $L = 30$, corresponding to a Hilbert space of size $\simeq 6 \times 10^{16}$). Our results suggest the existence of non-trivial multifractality in the ground state for a large range of interaction values. We find that an analysis of the generalised fractal dimensions for different densities exposes qualitatively the superfluid to Mott insulator transition. We furthermore explore different methods to quantitatively characterise the transition.

[1] E. Bogomolny. Multifractality in simple systems. Presentation at the conference "Complex patterns in wave functions: drums, graphs, and disorder" at the Kavli Royal Society Centre, UK (2012)

DY 69.4 Thu 15:30 Poster A

Quantum chaos in undoped graphene with long-range coulomb interaction — •Markus Klug[1], Mathias Scheurer[2], and Jörg Schmalian[1,3] — [1]Affiliation: Institute for Theoretical Condensed Matter Physics, Karlsruhe Institute of Technology, D-76131 Karlsruhe, Germany — [2]Department of Physics, Harvard University, Cambridge MA 02138, USA — [3]Affiliation: Institute of Solid State Physics, Karlsruhe Institute of Technology, D-76344 Eggenstein-Leopoldshafen, Germany

In the context of thermalization, we investigate the ability of electrons in undoped Graphene in the presence of long-range Coulomb interaction to scramble information. We therefore compute the Lyapunov exponent which represents the inverse time scale describing the exponential growth of certain out-of-time order correlation functions for intermediate times. The Lyapunov exponent λ is determined perturbatively to order $\mathcal{O}(1/N)$ where N is the number of fermion flavors. By doing so we are able to investigate the weak $\alpha \to 0$ and strong $\alpha \to \infty$ coupling regime with α being the fine structure constant determining the electron-electron interaction strength. By restoring $N = 4$ in case of graphene, we find in the strong coupling regime an exponent of order of the recently proposed bound, and for weak coupling a linear dependence on the coupling strength. The conducted analysis provides insights into the sensitiveness of out-of-time order correlators towards physical relaxation processes.

DY 69.5 Thu 15:30 Poster A

Including temperature in a wavefunction description of the spin boson model — •Michael Werther[1,2] and Grossmann Frank[1] — [1]TU Dresden, Institut für Theoretische Physik, Zellescher Weg 17, 01069 Dresden — [2]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden

The Davydov Ansatz is an efficient numerical tool for approximate solution of the Schrödinger-equation for different Hamiltonians. In recent works the D1-Ansatz has been successfully applied to different systems like the Holstein model or the quantum Rabi model[1], where it has proven to yield excellent results that are comparable to those of other numerical methods like HEOM or ML-MCTDH.[2]

Here we present how the Davydov Ansatz can be elegantly used to include temperature effects into the spin boson model, even in the strong coupling regime. In a frame in which all system and bath DOFs can be taken into account, we show how the powerful Dirac-Frenkel variational principle can be applied for approximate propagation of the full density matrix. As an outlook we show how numerical instabilities, arising especially from the multi Davydov Ansatz, can be overcome.

[1] M. Werther, F. Grossmann, J. Phys. A: Math. Theor., in press (2017)

[2] L. Chen, R. Borelli, Y. Zhao, J. Phys. Chem. A 121, 8757-8770 (2017)

DY 69.6 Thu 15:30 Poster A

Transport away from resonance channels in 4D symplectic maps — •Franziska Onken[1,2], Arnd Bäcker[1,2], and Roland Ketzmerick[1,2] — [1]TU Dresden, Institut für Theoretische Physik, Dresden — [2]MPI für Physik komplexer Systeme, Dresden

The dynamics of Hamiltonian systems (e.g., planetary motion, electron dynamics in nano-structures, chemical reactions) can be understood by studying the corresponding symplectic Poincaré maps. A central new feature in higher-dimensional systems is the transport in resonance channels. While such channels are usually investigated in frequency space, we visualize the relevant invariant objects in phase space revealing a highly non-trivial geometry. Especially the transport away from the channel is governed by families of hyperbolic 1D-tori and their stable and unstable manifolds. We provide a visualization of a turnstile in higher dimensions and an approach to measure the corresponding transport.

DY 69.7 Thu 15:30 Poster A

GOE-GUE-Poisson crossover in the nearest neighbor spacing distribution of magnetoexcitons — Frank Schweiner, •Patric Rommel, Jeanine Laturner, Jörg Main, and Günter Wunner — Institut für Theoretische Physik 1, University of Stuttgart, Germany

Until now only for specific transitions between Poissonian statistics (P), the statistics of a Gaussian orthogonal ensemble (GOE), or the statistics of a Gaussian unitary ensemble (GUE) analytical formulas for the level spacing distribution function have been derived within random matrix theory. We investigate arbitrary transitions in the crossover between all three statistics. To this aim we propose a fitting formula for the level spacing distribution function depending on two parameters [1]. Recent investigations on the Hamiltonian of excitons revealed that the combined presence of a cubic band structure and external fields breaks all antiunitary symmetries, and thus the nearest-neighbor spacing distribution of magnetoexcitons can exhibit all three statistics depending on the system parameters. Evaluating

the numerical results for magnetoexcitons in dependence on the excitation energy and on a parameter connected with the cubic valence band structure and comparing the results with the formula proposed allows us to investigate the level spacing dynamics in the crossover regime and to distinguish between regular and chaotic behavior as well as between existing or broken antiunitary symmetries. We also investigate the effect of the exciton-phonon interaction on the level statistics [2].

[1] F. Schweiner et al., Phys. Rev. E 96, 052217 (2017).
[2] F. Schweiner et al., Phys. Rev. B 96, 035207 (2017).

DY 69.8 Thu 15:30 Poster A

Signatures of multiple exceptional points in optical microdisk cavities — •Julius Kullig[1,2], Martina Hentschel[1], and Jan Wiersig[2] — [1]Institut für Physik, TU Ilmenau, Ilmenau, Deutschland — [2]Institut für Theoretische Physik, Otto-von-Guericke-Universität Magdeburg, Magdeburg, Deutschland

Optical microdisk cavities can confine light for very long times in extremely small volumes. However, due to radiation and evanescent leakage the optical modes are described by the non-Hermitian dynamics of open systems. One striking signature of this non-Hermitian physics are exceptional points (EPs) in parameter space at which at least two eigenvalues (complex frequencies) as well as their corresponding eigenstates (modes) coalesce.

Exceptional points in microdisk cavities have been shown to be very useful, e.g., for sensing devices. However, in lots of experimental setups EPs are adjusted in a rather fragile way e.g., via external particles or fibre tips.

In our poster we report on EPs formed by adjusting the properties of the cavity itself such as the refractive index profile and/or the boundary shape. Furthermore, we investigate situations where not a single but several EPs occur which is beyond a two-mode scenario of a single EP2 where two modes coalesce.

DY 69.9 Thu 15:30 Poster A

Transport along resonance channels in 4D symplectic maps — •Martin Langer[1], Roland Ketzmerick[1,2] und Arnd Bäcker[1,2] — [1]TU Dresden, Institut für Theoretische Physik, Dresden, Germany — [2]MPI für Physik komplexer Systeme, Dresden, Germany

A distinctive new feature of higher-dimensional systems is the possibility of Arnold diffusion, i.e. chaotic regions in phase space are all interconnected by the Arnold web. We study a designed 4D symplectic map with a regular region embedded in a chaotic sea, i.e. far away from the integrable regime. The model allows for generating specific resonance structures and shows a considerable drift of orbits in the chaotic region near these resonances. We investigate transport phenomena of ensembles of chaotic orbits in the vicinity of these resonances using 3D phase-space slices, frequency analysis, survival time plots, and chaos indicators.

DY 69.10 Thu 15:30 Poster A

Microwave graphs with time-dependent perturbations — •Tobias Hofmann[1], Aimaiti Rehemanjiang[1], Ulrich Kuhl[1,2], and Hans-Jürgen Stöckmann[1] — [1]Fachbereich Physik der Philipps-Universität Marburg, D-35032 Marburg, Germany — [2]Université Côte d'Azur, CNRS, Institut de Physique de Nice, 06108 Nice, France

The study of microwave billiards, where one Parameter depends on time, always has been a challenge. One possible parameter is the coupling to an external channel, which we have specifically in mind here. The difficulties arise from the need to apply perturbations of sufficient strength with frequencies of the order of the mean level spacing, typically of some MHz to be in the interesting regime.
In microwave networks time variations can be achieved by a means of a T junction, where one port is connected to a cable with a changeable terminator. A wave traveling through the cable being reflected at the end and returning to the T junction acquires a phase given by $\Delta\varphi = 2kl + \varphi_{\mathrm{term}}$, where $k = 2\pi\nu/c$ is the wave number, l the cable length and φ_{term} is the reflection phase. The expected periodic variation of the transmission from port 1 to port 2 with frequency ν was experimentally verified. If now the terminator of the cable is replaced by a variable diode, φ_{term} may be changed continuously by means of the diode voltage. Periodic modulations of the transmission with frequencies up to 10 MHz have already been achieved. By applying stochastic time variations also the study of "noisy graphs" [1] become feasible.

[1] D. Waltner, U. Smilansky, *J. Phys.* **A 47**, 355101 (2014).

DY 69.11 Thu 15:30 Poster A

Quantum localization on fractals in absorbing maps — •Konstantin Clauss[1], Martin Körber[1], Arnd Bäcker[1,2], and Roland Ketzmerick[1,2] — [1]TU Dresden, Institut für Theoretische Physik, Dresden — [2]MPI für Physik komplexer Systeme, Dresden

In chaotic quantum systems with escape a fundamental question concerns the phase-space localization of resonance states. It is known that a semiclassical description of individual states is given by some classical conditionally invariant measure with the same decay rate. It is not known, however, which specific measure is relevant for quantum mechanics. We combine conditional invariance with finite quantum resolution of the classical fractal chaotic saddle leading to a prediction of the corresponding measure. By this the typical phase-space distribution of resonance states for arbitrary decay rates is explained.

DY 69.12 Thu 15:30 Poster A

Frequency splittings in deformed optical microdisk cavities — •Chang-Hwan Yi[1], Julius Kullig[1,2], Chil-Min Kim[3], and Jan Wiersig[1] — [1]Institut für Theoretische Physik, Otto-von-Guericke-Universität Magdeburg, Postfach 4120, D-39016 Magdeburg, Germany — [2]Institute for Physics, Theoretical Physics II/Computational Physics Group, Technische Universität Ilmenau, Weimarer Straße 25,98693 Ilmenau, Germany — [3]Department of Emerging Materials Science, DGIST, Daegu 711-873, Korea

The frequency splitting of nearly degenerate optical modes in weakly deformed microdisks is investigated. According to a mirror-reflection symmetry of the cavity, the even and odd parity modes are studied. A semiclassical approach of dynamical tunneling (resonance-assisted tunneling) is implemented in order to explain the frequency splitting between clockwise and counterclockwise propagating waves. We deduce semiclassical predictions for the frequency splittings which agree well with full numerical calculations. As a representative deformation of an integrable and non-integrable systems, the ellipse and the quadrupole shapes are examined in detail. Different properties of the frequency splittings following the Dirichlet and dielectric boundary conditions are discussed.

DY 69.13 Thu 15:30 Poster A

Transport in disordered optical systems — •Florian Heyder and Martina Hentschel — Institute for Physics, Theoretical Physics II/Computational Physics Group, Technische Universität Ilmenau, Weimarer Straße 25, 98693 Ilmenau, Germany

It has been shown that electron transport through a quantum point contact in a two-dimensional electron gas leads to branching patterns of the scattered trajectories. We numerically investigate an analogue that is realized by a 2D optical system where light rays experience a correlated refractive index. The results show a branching behavior as well. We further examine the trajectory-statistics in our disordered systems and find, amongst other, a connection between the correlation length of the refractive index and the persistence of the branching.

DY 69.14 Thu 15:30 Poster A

Non-universal behaviour in branched flow — •Philipp Breul and Ragnar Fleischmann — Max-Planck-Institut für Dynamik und Selbstorganisation, Göttingen

When waves propagate in a weakly scattering complex medium they are strongly focused into branch-like structures on length scales much shorter than the mean-free-path. This *branched flow* is a very general phenomenon: wind driven ocean waves, light, sound, conduction electrons, tsunamis and even earth quakes are examples of waves that in a natural environment typically propagate through a complex medium and can exhibit branching.
Often the medium is best described as a Gaussian random field with intrinsic correlations. For a wide range of different functional forms of these correlations the statistics of branched flows have been found to show universal behaviour that only depends on a few characteristic quantities like the variance σ^2 and the integral correlation length ℓ_c of the fluctuations in the medium. For example does the typical length scale ℓ_b of branched flows scale like $\sigma^{-2/3}$. Inspired by the statistical structure of two-dimensional turbulent fields we study branched flows in media with pronounced anti-correlations that lead to vanishing integral correlation length in transverse direction to the flow. We find that such media exhibit strongly non-universal behaviour and the branchinglength scales like $\ell_b \sim \sigma^{-1}$.

DY 69.15 Thu 15:30 Poster A

An analytical approach to extend Fresnel laws to concave shaped interfaces — •Sebastian Luhn and Martina Hentschel — Institute for Physics, Group for Theoretical Physics II / Computational Physics, Technische Universität Ilmenau, Weimarer Str. 25, 98693 Ilmenau

Optical microcavities play an important role in many modern research fields. In particular it is interesting to study the reflection and refraction of beams at the interfaces of these cavities. The reflection of beams is described by Fresnel*s laws which apply to flat surfaces only and need to be corrected for curved interfaces. Since convex interfaces have been studied already, we perform these cor- rections for concave interfaces. We obtain the reflection coefficients by extend- ing the model of transfer matrices to cylindrical interfaces. Additionally we gain a relation between convex and concave Fresnel coefficients.

DY 69.16 Thu 15:30 Poster A

Optical microcavities for nanoparticle sensing — •Jakob Kreismann and Martina Hentschel — Technische Universität Ilmenau, Institut für Physik, Weimarer Str. 25, 98693 Ilmenau

Optical microcavties play an important role in nanophoptonic innovations and applications. Detection of nanoparticles or even single molecules is already a feasible method, for example by employing the resonant frequency shift due to the interaction of the particles with the evanescent field of a whispering gallery mode confined in a micro toroid or a micro sphere resonator. Usually these devices are designed to detect particles that attach on the side wall of the resonator. Here, we investigate a sensing method where particles can attach on the top surface, thereby overcoming the drawback of the small area of the side surface. We compare various, regular and chaotic, cavity geometries. The chaotic dynamics of the Limacon-shaped resonator are crucial to realize a broad field distribution along the top surface[1]. We perform three dimensional FDTD calculations to optimize the geometry by increasing the sensitive area surrounded by the evanescent field and characterize the sensing properties.

[1] J. Kreismann, S. Sinzinger, and M. Hentschel, Phys. Rev. A 95, 011801(R) (2017).

DY 69.17 Thu 15:30 Poster A

Power-law trapping in the volume-preserving Arnold-Beltrami-Childress map — •Swetamber Das[1] and Arnd Baeker[1,2] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden — [2]TU Dresden, Institut für Theoretische Physik, Dresden

While stickiness and power-law behavior of Poincaré recurrence statistics for two degree-of-freedom systems is well-understood, this remains to be an open problem for higher-dimensional systems. We study such trapping in the Arnold-Beltrami-Childress map which is an example of a three-dimensional volume-preserving system. If two action-like variables of the map are nearly conserved, the phase space displays tubular structures surrounded by a chaotic sea. Trapping occurs around these tubes and is investigated in phase space and frequency space to identify the underlying origin of stickiness and power-law trapping.

DY 69.18 Thu 15:30 Poster A

Mode spacing tuning analysis of a quantum-dash comb laser — •Patrick Fiala[1], Dominik Auth[1], Christoph Weber[1], Abderrahim Ramdane[2], and Stefan Breuer[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany — [2]CNRS Centre for Nanosciences and Nanotechnologies, C2N, Route de Nozay, 91460 Marcoussis, France

Monolithic self-mode-locked (SML) semiconductor lasers (SCLs) based on Quantum Dashs (QDh) offer stable and broad optical mode combs with mode spacings in the Multi-GHz range. In this contribution, we investigate experimentally the impact of time-delayed optical self-feedback (OFB) on the comb spacing tunability of a single-section QDh comb laser. The influence of varying optical feedback strengths and optical feedback delays is validated experimentally and by adapting a stochastic time-domain model.