DY 23: Quantum Chaos

Time: Wednesday 15:00–18:45 Location: ZEU 146

DY 23.1 Wed 15:00 ZEU 146

Spectral properties of microwave graphs with absorption — Markus Allgeier[1], Stefan Gehler[1], Sonja Barkhofen[1,3], Ulrich Kuhl[1,2], and •Hans-Jürgen Stöckmann[1] — [1]Fachbereich Physik, Universität Marburg — [2]Université de Nice Sophia-Antipolis, Nice, France — [3]Fachbereich Physik, Universität Paderborn

The influence of absorption on the spectra of microwave graphs has been studied experimentally. The microwave networks were made up of coaxial cables and T junctions. First, absorption was introduced attaching a 50 Ohm load to an additional vertex for graphs with and without time-reversal symmetry. The resulting level spacings distributions were compared with a generalization of the Wigner surmise in the presence of open channels proposed recently by Poli et al. [1]. A good agreement was found using an effective coupling parameter. Secondly, absorption was introduced along one individual bond via a variable microwave attenuator, and the influence of absorption on the length spectrum was studied. The peak heights in the length spectra corresponding to orbits avoiding the absorber were found to be independent of the attenuation, whereas the heights of peaks belonging to orbits passing the absorber once or twice showed the expected decrease with increasing attenuation.

[1] Poli et al., Phys. Rev. Lett. 108, 174101 (2012)

DY 23.2 Wed 15:15 ZEU 146

Experimental realization of superconducting quantum graphs — Barbara Dietz-Pilatus, Maksym Miski-Oglu, •Tetyana Skipa, and Achim Richter — Technische Universität Darmstadt, Institut für Kernphysik, Schlossgartenstraße 9, 64289 Darmstadt

We report on the design of superconducting quantum graphs, which will be realized with networks of two-dimensional microwave waveguides. We compare numerical results for the eigenvalue spectrum of microwave networks with that of the corresponding quantum graphs. Furthermore, the complete scattering matrix (S-matrix) of the microwave network was calculated and its properties are compared with theoretical predictions for the occurrence of topological resonances in open quantum graphs [1] and higher order correlation functions of the S-matrix [2]. The numerical calculations were performed with CST MW Studio. The scattering matrix is planned to be measured experimentally with superconducting microwave networks at liquid helium temperature in the frequency range from 14 to 40 GHz. This work was supported by the DFG within the Sonderforschungsbereich 634.

[1] S. Gnutzmann, H. Schanz and U. Smilansky, Phys. Rev. Lett. 110, 094101 (2013) [2] Z. Pluhar, H. A. Weidenmueller, Phys. Rev. Lett. 110, 034101 (2013)

DY 23.3 Wed 15:30 ZEU 146

Quantum graphs whose spectra mimic the zeros of the Riemann zeta function — •Jack Kuipers, Quirin Hummel, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany

One of the most famous problems in mathematics is the Riemann hypothesis: that the non-trivial zeros of the Riemann zeta function lie on a line in the complex plane. One way to prove the hypothesis would be to identify the zeros as eigenvalues of a Hermitian operator, many of whose properties can be derived through the analogy to quantum chaos. Using this, we construct a set of quantum graphs that have the same oscillating part of the density of states as the Riemann zeros, offering an explanation of the overall minus sign. The smooth part is completely different, and hence also the spectrum, but the graphs pick out the low-lying zeros.

arXiv:1307.6055

DY 23.4 Wed 15:45 ZEU 146

Time multiplexed photonic quantum walks — Andreas Schreiber[1,2], Fabian Katzschmann[1], •Sonja Barkhofen[1], Aurél Gábris[3], Peter Rohde[1], Kaisa Laiho[1,2], Martin Stefanák[3], Václav Potocek[3], Craig Hamilton[3], Igor Jex[3], and Christine Silberhorn[1] — [1]Applied Physics, University of Paderborn, Warburger Strasse 100, 33098 Paderborn, Germany — [2]Max-Planck-Institute for the Science of Light, Günther-Scharowsky-Str. 1 / Bau 24, 91058 Erlangen, Germany — [3]Department of Physics, Faculty of NuclearSciences and Physical Engineering, Czech Technical University in Prague, Brehová 7, 115 19 Praha, Czech Republic

Linear optical networks which comprise a large number of optical modes have been investigated intensively in various theoretical proposals. Most recently their relevance for studies of photonic quantum walk systems has attracted attention, because they can be considered as a standard model to describe the dynamics of quantum particles in a discretized environment and serve as a simulator for other quantum systems, which are not as readily accessible. A key element for a versatile simulator is the ability to dynamically control the quantum-coin, which is the main entity responsible for the evolution of the quantum walk. The utilization of the polarization state as coin state allows for easy manipulation by introducing controlled phase shifts through an electro optic modulator to selectively modify the coin state. This enables us to tune interaction strengths and patterns to simulate different kinds of particles or environments and thus enhancing the abilities of photonic experiments.

DY 23.5 Wed 16:00 ZEU 146

Asymmetric backscattering in waveguide-coupled microdisk resonators — •Johannes Kramer and Jan Wiersig — Otto-von-Guericke-Universität Magdeburg, 39016 Magdeburg

Recently, it has been discovered that the coherent backscattering of counter-propagating waves in deformed or perturbed microdisk cavities can be asymmetric provided that the cavity does not possess a mirror-reflection symmetry [1,2]. This leads to the appearance of nonorthogonal pairs of copropagating optical modes with a preferred sense of rotation. In the extreme case the pair of modes coalesce at a so-called exceptional point. We present finite-difference time-domain (FDTD) simulations which indicate that the asymmetric backscattering can be unambiguously identified in transmission and reflection experiments on waveguide-coupled microdisks.

[1] J. Wiersig, A. Eberspächer, J.-B. Shim, J.-W. Ryu, S. Shinohara, M. Hentschel, and H. Schomerus, Phys. Rev. A 84, 023845 (2011)
[2] J. Wiersig, Phys. Rev. A 84, 063828 (2011)

DY 23.6 Wed 16:15 ZEU 146

Manifestation of periodic orbits in triangular microlasers — •Stefan Bittner[1], Clément Lafargue[1], Christian Ulysse[2], Alain Grigis[3], Joseph Zyss[1], and Mélanie Lebental[1] — [1]Quantum and Molecular Photonics Laboratory, ENS Cachan — [2]Laboratory for Photonics and Nanostructures, Marcoussis — [3]Laboratoire Analyse, Géométrie et Applications, University Paris 13

One of the main interests in open dielectric resonators is to understand the correspondence between their wave dynamics and the classical ray dynamics. We present experiments with flat organic microlasers of triangular shape. The aim of the experiments was to understand the relation between the lasing properties of the microlasers and the periodic orbits (POs) in the corresponding triangular billiards. Triangles are of special interest since they are the most simple polygons and because the number and types of POs in general triangular billiards remain unknown. The spectra and far-field distributions of the microlasers were measured and photographs of the lasing cavities themselves were taken. These data allowed to identify the underlying POs. Several types of triangles with different kinds of classical dynamics and POs were studied. In some cases all lasing modes were based on a single family of POs whereas in other cases a competition between modes based on different types of POs was observed. Furthermore, some lasing modes seemed to be based on diffractive POs, i.e., orbits that impinge directly on a diffractive corner. Such modes could be used as a tool to further investigate the diffraction at dielectric corners.

DY 23.7 Wed 16:30 ZEU 146

Goos-Hänchen shift and Fresnel filtering at curved interfaces - Analytic and numeric results — •Pia Adam, Jakob Kreismann, and Martina Hentschel — Technische Universität Ilmenau, Institut für Physik, Ilmenau, Germany

Describing confined light bundles by rays obeying the laws of geometrical optics is a powerful tool even in the regime where, strictly speaking, full wave dynamics should be applied. When considering structures at length scales of a few wavelengths, however, semiclassical effects have to be taken into account. These deviations from the laws of geometrical optics are the Goos-Hänchen shift which is long known

for planar interfaces, and the Fresnel filtering effect. In this work we derive analytical expressions to describe the Goos-Hänchen shift and Fresnel filtering at curved interfaces in the regime of total reflection as well as for partial reflection. These analytical results are supported by numerical simulations.

15 min break

DY 23.8 Wed 17:00 ZEU 146

Resonance chains in the open 3-disk system — •Tobias Weich[2], Sonja Barkhofen[1], Ulrich Kuhl[3], Charles Poli[4], and Henning Schomerus[4] — [1]Fachbereich Physik, Philipps-Universität Marburg, Renthof 5,35032 Marburg, Germany — [2]Fachbereich Mathematik, Philipps-Universität Marburg, Hans-Meerwein-Straße,35032 Marburg, Germany — [3]Laboratoire de Physique de la Matière Condensée, CNRS UMR 7336, Université de NiceSophia-Antipolis, F-06108 Nice, France — [4]Department of Physics, Lancaster University, Lancaster LA1 4YB, UK

In ballistic open quantum systems one often observes that the resonances in the complex-energy plane form a clear chain structure. Taking the open 3-disk system as a paradigmatic model system, we investigate how this chain structure is reflected in the scattering states and how it is connected to the underlying classical dynamics. Furthermore we present a simple open quantum graph model consisting of two edges that shows surprisingly similar behaviour in its resonance structure and scattering states.

DY 23.9 Wed 17:15 ZEU 146

Multifractals in Quantum Chaos — •Moritz Schönwetter and Eduardo G. Altmann — MPIPKS, Dresden

Fractal properties of open chaotic systems are known to play an important role in their corresponding quantum systems. Well studied examples are the localisation of long lived states on fractal structures in the classical phase space and the fractal Weyl law connecting the asymptotic resonance density with the fractal dimension D_0 of the classical invariant set. In numerous physically relevant cases the opening is not complete but results from partial absorption and partial reflection (e.g., of the intensity of optical rays), in which case the classical system is no longer characterised by D_0 but by the full multi-fractal spectrum of Rényi dimensions D_q. Here we study the influence of partial reflection and multi-fractality of the underlying classical system on spectral properties of the quantum mechanical counterpart.

DY 23.10 Wed 17:30 ZEU 146

Hierarchical Resonance States and Fractal Weyl Laws — •Martin Körber[1], Matthias Michler[1], Arnd Bäcker[1,2], and Roland Ketzmerick[1,2] — [1]Technische Universität Dresden, Institut für Theoretische Physik, 01062 Dresden, Germany — [2]MPI für Physik komplexer Systeme, 01187 Dresden, Germany

The chaotic dynamics of generic Hamiltonian systems is governed by partial barriers. They also strongly influence the system's quantum-mechanical properties. In closed systems, the localization of eigenstates around a partial barrier universally depends on the ratio of the flux across the partial barrier and the effective size of Planck's cell, only [1]. In open systems, however, we observe that partial barriers imply localization of resonance states apart from this criterion. This gives rise to hierarchical fractal Weyl laws in generic systems [2]. We present an argument for the existence of these localized resonance states and study their parameter dependence. We design a model system that allows us to distinguish between the universal influence of the opening and the subtle contribution from the chaotic saddle.

[1] Phys. Rev. Lett. **109**, 234101 (2012)
[2] Phys. Rev. Lett. **111**, 114102 (2013)

DY 23.11 Wed 17:45 ZEU 146

The Weyl expansion for systems of identical particles - Spatial Friedel oscillations for excited many-body states — •Quirin Hummel, Juan Diego Urbina, Markus Biberger, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, Germany

For single-particle billiard systems, the smooth part of the density of states (DOS) in a semiclassical approximation is known as the Weyl expansion. In [1] we study a corresponding expansion for the smooth part of the many-body DOS in fermionic and bosonic systems including physical boundary effects. Here, we exploit this framework to give formal and explicit expressions for the smooth part of the local density of states (LDOS) in such systems. Comparing the many-body LDOS with the average behaviour of the spatial density of a system of non-interacting fermions near the ground state, known as Friedel oscillations, we show that our expressions can be understood as an extension of the latter to excited many-body energies.

[1] arXiv 1210.5748

DY 23.12 Wed 18:00 ZEU 146

Resonance Assisted Tunneling in Mixed Systems using Integrable Approximations — •Clemens Löbner[1,2], Julius Kullig[1], Normann Mertig[1,2], Steffen Löck[1,3], Arnd Bäcker[1,2], and Roland Ketzmerick[1,2] — [1]Technische Universität Dresden, Institut für Theoretische Physik, 01062 Dresden — [2]MPI für Physik komplexer Systeme, 01187 Dresden — [3]Technische Universität Dresden, Oncoray - National Center for Radiation Research in Oncology, 01307 Dresden

Generic Hamiltonian systems have a mixed phase space in which regions of regular motion are embedded in regions of chaotic motion. Quantum mechanically these regions are connected by regular-to-chaotic tunneling. In the presence of nonlinear resonances, this effect is strongly enhanced and is therefore called resonance-assisted tunneling.

We present a theoretical description of resonance-assisted tunneling in mixed systems using an integrable approximation of the regular region. We introduce a new method [1] based on canonical transformations to construct the integrable approximation and extend this method to systems with resonances. The resulting approximation is used for the prediction of regular-to-chaotic tunneling rates. We show results for the generic standard map.

[1] C. Löbner, S. Löck, A. Bäcker, and R. Ketzmerick: Phys. Rev. E 88, 062901 (2013)

DY 23.13 Wed 18:15 ZEU 146

Semiclassical theory of bosonic many-body scattering: a non-perturbative Green's function approach — •Josef Michl, Thomas Engl, Markus Biberger, Juan-Diego Urbina, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, Germany

Semiclassical techniques have so far been applied mainly to single-particle systems. For these systems they provide a powerful toolbox to study interference effects and allow for analytical calculations even in the presence of classical chaos.
Previously, we have succeeded in constructing a semiclassical approximation of the propagator in bosonic Fock state representation which is based on real actions and hence shows interference in Fock space explicitly[1]. This opens the possibility to define semiclassical many-body Green's functions, the natural objects required to study stationary many-body scattering. The main advantage of such an approach is that it provides a non-perturbative method to address directly the full many-body Green's function, contrary to standard methods based on Dyson expansions. However, this program requires a proper theory of many-body scattering, beyond the usual picture based on single-particle observables like the current. We present an overview of the conceptual and technical basis of many-body stationary scattering, and show how the many-body semiclassical Green's function can be used in this context.

[1] Thomas Engl *et al.*, arXiv:1306.3169.

DY 23.14 Wed 18:30 ZEU 146

Quantum-classical correspondence and critical phenomena in anisotropic Kepler problem — •Kazuhiro Kubo — Max-Planck-Institut für Physik Komplexer Systeme, Dresden, Germany

Recently the importance of entanglement analysis in the Anderson localization is well recognized with respect to the multifractality of a wave function near the criticality. From a random matrix model for the critical statistics, García-García and Verbaarschot conjectured in 2003 that the Anderson localization closely relates to the critical phenomena in the quantum chaos. The crucial test can be done by investigating the relation between the wave function multifractality and the compressibility of energy eigenvalues. As a suitable model we choose the anisotropic Kepler problem (AKP) — the hydrogen atom with electron-mass anisotropy parameter. We have recently performed an extensive numerical calculation for the AKP quantum states using two independent basis sets (sturmian and harmonic-wave function basses). We hope we can present a preliminary account on this issue.