DY 19: Quantum Chaos

Time: Wednesday 14:00–18:15 Location: H38

Topical Talk DY 19.1 Wed 14:00 H38
Chaotic Scattering in Microwave Billiards With and Without Time-Reversal Invariance — •Barbara Dietz[1], Thomas Friedrich[2], Hanns L. Harney[3], Maksim Miski-Oglu[1], Achim Richter[1,4], Florian Schäfer[1,5], and Hans A. Weidenmüller[3] — [1]TU Darmstadt, D-64289 Darmstadt — [2]GSI Helmholtzzentrum für Schwerionenphysik GmbH, D-64291 Darmstadt — [3]MPI für Kernphysik, D-69029 Heidelberg — [4]ECT*, Villa Tombosi, I-38100 Villazzano — [5]LENS, University of Florence, I-50019 Sesto-Fiorentino

We discuss measurements of scattering amplitudes of a chaotic microwave resonator in the regime of isolated and overlapping resonances. Below a certain excitation frequency the resonator simulates a quantum billiard, whose eigenvalues manifest themselves in the spectra as resonances with average spacing d and width Γ. Violation of time-reversal (T) invariance is achieved with a magnetized ferrite inside the cavity. The experimental observables are complex scattering (S)-matrix elements, measured for the resonator with and without T invariance as a function of frequency. Particular emphasis is given to S-matrix correlation functions in the regime of weakly overlapping resonances, i.e. $\Gamma/d \simeq 1$, and their comparison to results from the theory of chaotic scattering developed in nuclear reaction theory. We also present results on the distribution of the S-matrix elements and higher order correlation functions. Here, a focus is the transition from the regime of weakly overlapping resonances to the Ericson regime, i.e. from non exponential to exponential decay of the system of resonances. This work was supported by the DFG within the SFB634

DY 19.2 Wed 14:30 H38
Geometric Phases of Exceptional Points in Time-Reversal Noninvariant Systems — Stefan Bittner[1], Barbara Dietz-Pilatus[1], Pedro Oria Iriarte[1], Maksim Miski-Oglu[1], Achim Richter[1,3], Hans A. Weidenmüller[2], Hanns L. Harney[2], and •Florian Schäfer[1,4] — [1]Institut für Kernphysik, Schlossgartenstraße 9, 64289 Darmstadt — [2]Max-Planck-Institut für Kernphysik, 69029 Heidelberg — [3]ECT*, Villa Tambosi, I-38100 Villazzano (Trento), Italy — [4]LENS, University of Florence, I-50019 Sesto-Fiorentino (Firenze), Italy

The eigenvectors of a two level system described by a non-Hermitian Hamiltonian coalesce at a so-called Exceptional Point, a phenomenon already investigated in numerous systems. In general, for a two-dimensional Hamiltonian the two components of each eigenfunction define an enclosing angle ϕ. Past experiments established for time-reversal invariant systems at an Exceptional Point a universal phase $\phi = \pi$. Here, we present results on experiments in microwave billiards with partial time-reversal invariance violation, induced by the presence of a magnetized ferrite. Two control parameters allow for a variation of the Hamiltonian. The experiments explore the parameter space in vicinity the of and at an Exceptional Point. The data allow for a reconstruction of the complete, complex-valued Hamiltonian. Using this information we demonstrate a sensitive dependence of ϕ at an Exceptional Point on the strength of time-reversal invariance violation.

This work is supported by DFG through SFB 634.

DY 19.3 Wed 14:45 H38
Semiclassical Transport and Diffraction Effects in Circular Billiards — •Tobias Dollinger[1], Daniel Waltner[1], Iva Březinová[2], Michael Wimmer[3], Klaus Richter[1], and Joachim Burgdörfer[2] — [1]Institute for Theoretical Physics, University of Regensburg, Universitätsstraße 31, 93053 Regensburg, Germany — [2]Institute for Theoretical Physics, Vienna University of Technology, Wiedner Hauptstraße 8-10, 1040 Vienna, Austria — [3]Leiden Institute of Physics, Leiden University, Niels Bohrweg 2, 2333 CA Leiden, The Netherlands

In the present work we investigate the magnetoconductance of two dimensional circular billiards by numerical and analytical means. In ballistic chaotic cavities semiclassical theories have provided remarkably accurate analytical descriptions of interference phenomena, such as weak localization. However, previous examinations of the circular billiard have indicated that the standard trajectory based techniques do not describe the weak localization effect in this nongeneric setup sufficiently well. The significance of diffractive orbits in this context has been emphasized in earlier works. This is supported by our numerical findings. Moreover we present a semiclassical formalism specialized for the description of the underlying classical system and discuss the consequences of incorporating diffraction.

DY 19.4 Wed 15:00 H38
Trace Formula for Dielectric Cavities — •Stefan Bittner[1], Barbara Dietz[1], Maksim Miski-Oglu[1], Pedro Oria-Iriarte[1], Birgit Quast[1], Achim Richter[1,2], and Florian Schäfer[1,3] — [1]Institut für Kernphysik Darmstadt — [2]ECT* Trento — [3]Università degli Studi di Firenze

Microlasers and dielectric microcavities have gained great interest due to possible applications in e.g. telecommunications and as a new type of wave-dynamical billiards. Especially the correspondence between ray- and wave-optics in these systems is being intensely studied. Recently, a trace formula for dielectric cavities has been proposed [1], which provides a connection between the density of states of the cavity and the periodic orbits of the corresponding billiard. In order to test this trace formula experimentally, we have measured the spectra of circular and square dielectric microwave resonators. The length spectra were compared to the prediction of the trace formula and large deviations were observed. These are attributed to the fact that only resonances with long lifetimes can be observed experimentally. Moreover, the systematics of observed and unobserved modes must be taken into account for an understanding of the experimental length spectra. The work presented in this talk was supported by DFG within SFB 634.

[1] Bogomolny *et al.*, Phys. Rev. E **78**, 056202 (2008).

DY 19.5 Wed 15:15 H38
Fractal Weyl law in a three-disk microwave system — •Alexander Potzuweit, Ulrich Kuhl, and Hans-Jürgen Stöckmann — Fachbereich Physik, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany

The transport properties of systems with a classical chaotic repeller are particularly intriguing. It had been predicted that the distribution of the poles of the scattering matrix should obey a fractal Weyl law with an exponent depending on the fractal dimension of the classical chaotic repeller[1]. From microwave measurements in an open symmetry-reduced three-disk system, we extract the resonances using the powerful technique of harmonic inversion[2]. By variation of the distance-to-radius parameter we find a qualitative good agreement between the experimental parameter dependence and the prediction from the fractal Weyl law.

[1] W. T. Lu, S. Sridhar, M. Zworski, Phys. Rev. Lett. 91, 154101(2003)
[2] J. Wiersig, J. Main, Phys. Rev. E 77, 36205(2008)

DY 19.6 Wed 15:30 H38
Regular-to-Chaotic Tunneling Rates: From the Quantum to the Semiclassical Regime — •Steffen Löck[1], Arnd Bäcker[1], Roland Ketzmerick[1], and Peter Schlagheck[2] — [1]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Germany — [2]Département de Physique, Université de Liège, 4000 Liège, Belgium

In systems with a mixed phase space, regular islands are dynamically separated from the chaotic sea, while quantum mechanically these phase-space regions are connected by dynamical tunneling. We derive a prediction of dynamical tunneling rates of regular states to the chaotic sea by combining the direct regular-to-chaotic tunneling mechanism in the quantum regime with an improved resonance-assisted tunneling theory in the semiclassical regime. For systems with one or multiple dominant nonlinear resonances we find excellent agreement to numerics.

DY 19.7 Wed 15:45 H38
Dynamical tunneling in 4D area preserving maps — Arnd Bäcker, Roland Ketzmerick, and •Martin Richter — Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

Higher dimensional systems show a very involved phase-space structure including complex regular regions interwoven with the Arnol'd web. For such systems we want to investigate the regular-to-chaotic tunneling rates. We focus on 4D area preserving maps. As a first step we introduce some simple models with well separated chaotic and regular regions and visualize them by sections through the 4D phase space. We present a prediction of tunneling rates using the fictitious integrable system approach which has been developed for lower dimensional systems.

15 min. break

DY 19.8 Wed 16:15 H38

Levy distribution in many-body quantum systems — •Sergey Denisov, Alexey V. Ponomarev, and Peter Hanggi — Institute of Physics, University of Augsburg, Germany

Levy distribution is known to describe a whole range of complex phenomena: classical chaotic transport, processes of subrecoil laser cooling, fluctuations of stock market indices, time series of single molecule blinking events, bursting activity of small neuronal networks, to name a few. The appearance of Levy distribution in a system output is a strong indicator of a long-range correlation "skeleton" which conducts system intrinsic dynamics.

Using two complimentary approaches, the canonical and the grand-canonical formalisms, we discovered that the momentum distribution of N strongly interacting (hard-core) bosons at finite temperatures confined on a one-dimensional optical lattice obeys the Levy distribution. The tunable Levy spline reproduces momentum distributions up to one recoil momentum. Our finding allows for calibration of complex quantum many-body states by using a unique scaling exponent.

[1] A. V. Ponomarev, S. Denisov and P. Hanggi, arXiv:0907.4328

DY 19.9 Wed 16:30 H38

Signatures of quantum chaos in mesoscopic many-body effects — •Martina Hentschel and Georg Röder — MPI für Physik komplexer Systeme, Dresden

Many-body effects have been a key interest in condensed matter physics for many years. We study them for mesoscopic, rather than for bulk, systems in the context of photoabsorption spectra (x-ray edge problem) and focus on deviations from the bulk (metallic) case as well as on quantum-chaos signatures such as the geometry-dependence of the photoabsorption cross section. It is determined by two counteracting many-body effects, known as Anderson orthogonality catastrophe and Mahan's exciton. They result from the system's many-body response to the sudden, localized perturbation given by the core hole that is left behind when the x-ray excites an electron. We find characteristic deviations from the metallic case that are strongest near the system boundary, as a result of the prominent correlation between the wave function (that drops to zero) and its derivative (that is correspondingly large). As a consequence, the photoabsorption cross section develops a pronounced peak, in contrast to a rounded signature for metals and a slight peak away from the system boundary. We furthermore study the dependence on the system geometry and find that level degeneracies, possible in ballistic quantum dots of regular, rather than chaotic, shape trigger considerable changes in the orthogonality catastrophe response that altogether becomes somewhat stronger.

DY 19.10 Wed 16:45 H38

Increase of conductance fluctuations with Ehrenfest time in presence of tunnel barriers — •Daniel Waltner[1], Jack Kuipers[1], Cyril Petitjean[1], Philippe Jacquod[2], and Klaus Richter[1] — [1]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany — [2]Physics Department, University of Arizona, Tucson, AZ 85721, USA

We study the effect of tunnel barriers on the Ehrenfest-time dependence of universal conductance fluctuations (UCF) for classically chaotic systems. In the case of strong coupling to the leads UCF are independent of the Ehrenfest time: this was observed numerically in [1] and then explained analytically in [2]. In the case of very opaque tunnel barriers, that we consider here, an increase of UCF with increasing Ehrenfest time is observed in numerical simulations that we address analytically in this talk.

[1]J. Tworzydło *et al.*, Phys. Rev. B **69**, 165318 (2004); P. Jacquod and E. V. Sukhorukov, Phys. Rev. Lett. **92**, 116801 (2004).
[2]P. W. Brouwer and S. Rahav, Phys. Rev. B **74**, 075322 (2006).

DY 19.11 Wed 17:00 H38

Coupling fidelity in a microwave billiard — •Bernd Köber[1], Ulrich Kuhl[1], Hans-Jürgen Stöckmann[1], Dmitry Savin[2], Thomas Gorin[3], and Thomas Seligman[4] — [1]Fachbereich Physik, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany — [2]Department of Mathematical Sciences, Brunel University, Uxbridge UB8 3PH, UK — [3]Departamento de Fisica, Universidad de Guadalajara, Guadalajara C.P. 44840, Jalisco, Mexico — [4]Instituto de Ciencias Fisicas, Universidad Nacional Autonoma de Mexico, Cuernavaca, Mexico

In former microwave fidelity studies we found for global perturbation an agreement with prediction from random matrix theory [1], whereas in case of a local perturbation an algebraic decay was found [2]. In this presentation we use the coupling to an external channel as a perturbation parameter, which is inherent to systems to be used for quantum computing. The scattering fidelity is the parametric cross-correlation function, normalized by the auto-correlation function $f^{(\lambda)}(t) = \langle \hat{S}^{(\lambda)}(t)\hat{S}(t)\rangle / \langle |\hat{S}(t)|^2\rangle$, where $\hat{S}(t)$ is a scattering matrix element in the time domain, the brackets denote an ensemble average, and λ is the perturbation parameter. The cross-correlation can be rewritten as an auto-correlation with an effective parameter, allowing a direct application of the VWZ approach [3]. The experimentally found fidelity decay is algebraic and in perfect agreement with theory.

[1] R. Schäfer et al., Phys. Rev. Lett. 95184102 (2005).
[2] R. Höhmann et al., Phys. Rev. Lett. 100, 124101 (2008).
[3] J. J. M. Verbaarschot et al., Phys. Rep. 129, 367 (1985).

DY 19.12 Wed 17:15 H38

The density of states of chaotic Andreev Billiards — •Thomas Engl, Jack Kuipers, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg,Germany

Quantum cavities, like quantum dots, have markedly different properties depending on whether their classical counterparts are chaotic or not. Connecting a superconductor to such a dot leads to remarkable effects, most notably the appearance of a hard gap in the excitation spectrum of chaotic systems. Andreev billiards are interesting examples of structures built by superconductors connected to a normal metal, and each time an electron hits the superconducting part it is retro-reflected as a hole (and vice-versa).

Using a semiclassical framework for systems with chaotic dynamics, we show how this reflection, along with the interference due to subtle correlations between the classical paths of electrons and holes inside the system, are ultimately responsible for this phenomenon. Furthermore, we are able to see how a magnetic field inside the system or phases inside the superconductor can remold and eventually suppress the gap.

DY 19.13 Wed 17:30 H38

Moments of the Wigner delay times — Gregory Berkolaiko[1] and •Jack Kuipers[2] — [1]Department of Mathematics, Texas A&M University, College Station, TX 77843-3368, USA — [2]Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany

The Wigner time delay is a measure of the time spent by a particle inside the scattering region of an open system. For chaotic systems, the statistics of the individual delay times (whose average is the Wigner time delay) are thought to be well described by random matrix theory. Here we present a semiclassical derivation showing the validity of random matrix results. In order to simplify the semiclassical treatment, we express the moments of the delay times in terms of correlation functions of scattering matrices at different energies. In the semiclassical approximation, the elements of the scattering matrix are given in terms of the classical scattering trajectories, requiring one to study correlations between sets of such trajectories. We describe the structure of correlated sets of trajectories and formulate the rules for their evaluation to the leading order in inverse channel number. This allows us to derive a polynomial equation satisfied by the generating function of the moments. Along with showing the agreement of our semiclassical results with the moments predicted by random matrix theory, we infer that the scattering matrix is unitary to all orders in the semiclassical approximation.

Arxiv:0910.0060

DY 19.14 Wed 17:45 H38

Fano resonances under the influence of absorption or decoherence — •Stefan Gehler[1], Ulrich Kuhl[1], Hans-Jürgen Stöckmann[1], Andreas Bärnthaler[2], Stefan Rotter[2], Florian Libisch[2], and Joachim Burgdörfer[2] — [1]Fachbereich Physik, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany — [2]Institute for Theoretical Physics, TU Vienna, A-1040 Vienna, Austria

We present theoretical and experimental results on the modification of Fano resonances [1] due to the effect of decoherence [2]. Specifically, our theoretical calculations demonstrate how the asymmetry parameter of Fano resonances in the transmission of microwaves through a metal cavity is affected by the dissipation in the cavity walls. In these dissipative systems the way in which the Fano asymmetry parameter deviates from its fully coherent value is characteristically different from dephasing systems where flux is conserved. These characteristic differences are explored and confirmed in microwave experiments on rectangular metal cavities with varying dissipation strengths.

[1]U. Fano, Phys. Rev. 124 (1961) 1866

[2]S. Rotter, U.Kuhl, F. Libisch, J. Burgdörfer, H.-J. Stöckmann, Physica E 29 (2005) 325-333

DY 19.15 Wed 18:00 H38

Transport and weak localisation of Bose-Einstein condensates in two-dimensional billiards — •Timo Hartmann[1], Juan Diego Urbina[1], Cyril Petitjean[1], Klaus Richter[1], and Peter Schlagheck[2] — [1]Institute for Theoretical Physics, University of Regensburg, D-93040 Regensburg, Germany — [2]Département de Physique, Université de Liège, 4000 Liège, Belgium

The possibility to induce artificial magnetic gauge potentials for matter waves [1] and to create almost arbitrarily shaped confinement potentials [2] makes it now interesting and feasible to study coherent transport of Bose-Einstein condensates through various mesoscopic structures. Previous theoretical studies have focused on the question how coherent backscattering in disordered potentials is modified by the presence of the atom-atom interaction [3]. We now study the analogous scenario of weak localisation in ballistic billiard geometries which exhibit chaotic classical dynamics. Therefore we numerically investigate the quasi-stationary propagation of a condensate through such structures within the mean-field approximation. The transmission is measured as a function of the magnetic field and of the non-linearity. A trend towards inversion of the signal of weak localisation is visible. We discuss the results from a semiclassical point of view.

[1] Y.-J. Lin et al., Phys. Rev. Lett. **102** 130401 (2009)
[2] K. Henderson et al., New J. Phys. **11**, 043030(2009)
[3] M. Hartung et al., Phys. Rev. Lett. **101**, 020603 (2008).