DY 23: Quantum Chaos

Time: Tuesday 10:00–12:15 Location: EB 107

DY 23.1 Tue 10:00 EB 107

Universal two-point correlations in many-body systems: the Random Wave Model in Fock space — •Juan-Diego Urbina and Klaus Richter — Institute for Theoretical Physics, University of Regensburg, Germany

Forty years after its discovery, Berry's Random Wave Model with its several modifications and variants is still the most powerful tool to understand the morphology of eigenfunctions in first-quantized chaotic (non-disordered) systems[1]. Surprisingly, the obvious question about how to construct a similarly powerful approach in the realm of interacting many-body quantum systems, with their natural description is Fock space, recieved little attention. Recently, however, this situation has dramatically changed due to the intimate connection between Berry's ansatz and the so-called eigenstate thermalization hypothesis.

While the first steps into the systematic study of the statistical distribution of Fock-space amplitudes in many-body eigenfunctions have been taken for the unexplored case of clean systems[3], a key element of a possible Random Wave Model in fock space is the universality of the two-point correlator. In this talk, we present the semiclassical theory that predicts such universal behavior and discuss its main features.

[1] See J. D. Urbina and K. Richter, Adv. Phys. (62) 363 (2013) for a recent review.
[2] M. Rigol, V. Dunjko, and M. Olshanii, Nature (452) 854 (2008).
[3] W. Beugeling, A. Baecker, R. Moessner, and M. Haque, arXiv:1710.11433 (2017).

DY 23.2 Tue 10:15 EB 107

Color mixing and beam shaping with chaotic light guides — •Julia Unterhinninghofen — Hochschule Koblenz, Konrad-Zuse-Str. 1, 56075 Koblenz

The dynamics of billiard systems has been used a model system for various applications. I.e., the ray dynamics of optical microcavities [1] for lasers and sensors can be understood as the classical nonlinear dynamics of an open billiard, while mode development and light output correspond to the dynamics of a quantum billiard. For many applications, shapes corresponding to chaotic or mixed billiards are desirable.

The ray dynamics of chaotic Bunimovich and Sinai billiards has also been used [2] to model the efficiency of color mixing in light guides with a cross-section corresponding to a chaotic billiard. Here, this approach is expanded to account for the openness (because of Fresnel losses) of such systems; we also investigate different smooth light guide cross-sections which can be easiliy fabricated. The results are applied to LED color mixing (corresponding to mixing in the spatial direction) as well as beam shaping (corresponding to mixing in the angular direction, i.e. in the far-field).

[1] J. U. Nöckel, A. D. Stone. Nature 385, 45 (1997)
[2] T. Bonenberger, J. Baumgart, S. Wendel, C. Neumann. Proc. SPIE 8641 (2013)

DY 23.3 Tue 10:30 EB 107

Semiclassical Description of Resonance-Assisted Tunneling in Deformed Optical Microdisks — •Felix Fritzsch[1,2], Arnd Bäcker[1,2], Roland Ketzmerick[1,2], and Normann Mertig[1,2,3] — [1]TU Dresden, Institut für Theoretische Physik, Dresden — [2]MPI für Physik komplexer Systeme, Dresden — [3]Department of Physics, Tokyo Metropolitan University, Tokyo

In optical microcavities dynamical tunneling allows for finite lifetimes of whispering gallery modes, which are classically confined by total internal reflection. The lifetimes of such modes may drastically decrease by resonance-assisted tunneling due to the presence of classical nonlinear resonances of the ray dynamics. We present a fully semiclassical description of resonance-assisted tunneling in deformed optical microdisks based on a generalization of the theory for quantum maps. This provides an intuitive ray-based picture of resonance-assisted tunneling and spoiling of Q-factors using only classical phase-space properties.

DY 23.4 Tue 10:45 EB 107

Ray-Wave correspondence in Optical and Graphene Billiards — •Guido Natura and Martina Hentschel — Technische Universität Ilmenau, Ilmenau

The development of optical resonators became essential for the improvements of optical devices such as filters, sensors or lasers. A promising application are microcavities, which allow the trapping of light by means of internal reflection. Here we are considering graphene Billiards where the resonator geometry is created by a step and a barrier on a graphene surface and allows the trapping of carriers inside [1,2]. These are assumed to behave as relativistic fermions in a finite domain as in the Neutrino *Berry-Mondragon-Billiards* [3]. The objective of this work is the invesitigation of whispering gallery modes in graphene Billiards and the study of a possible ray-wave-correspondence in the relativistic case.

[1] Katsnelson, M.I., Novoselov, K.S. and Geim, A.K., Chiral tunneling and the Klein paradox in graphene, *Nature Physics*, **2**, 620-625 (2006)
[2] Zhao et al., Creating and probing electron whispering-gallery modes in graphene, *Science*, **348**, 672-675 (2015)
[3] Berry, M.V. and Mondragon, R.J., Neutrino Billiards: Time-Reversal Symmetry-Breaking Without Magnetic Fields *Proc. Royal. Soc. A: Mathematical, Physical and Engineering Sciences*, **412**, 53-74 (1987)

15 min. break

DY 23.5 Tue 11:15 EB 107

3D billiards: visualization of regular structures and trapping of chaotic trajectories — •Markus Firmbach[1,2], Steffen Lange[1], Roland Ketzmerick[1,2], and Arnd Bäcker[1,2] — [1]TU Dresden, Institut für Theoretische Physik, Dresden — [2]MPI für Physik komplexer Systeme, Dresden

Billiard systems, in which a point particle moves freely within some domain and undergoes elastic reflections at the boundary, play an important role in many area of physics, e.g. for optical microcavities. The phase-space of 2D billiards is easily displayed on a 2D Poincaré section. In contrast, 3D billiards lead to a 4D Poincaré map which is challenging to visualize. By means of the recently introduced 3D phase-space slices an intuitive representation of the organization of the mixed phase-space with regular and chaotic dynamics is obtained. Of particular interest for applications are constraints to classical transport between different regions of phase-space which can be detected by the statistics of Poincaré recurrence times. For a specific example of a 3D billiard we observe a slow power-law decay caused by long-trapped trajectories whose origin is analyzed in phase-space and frequency-space.

DY 23.6 Tue 11:30 EB 107

Microwave graphs: Transition from Symplectic to Orthogonal Symmetry — •Martin Richter[1], Aimaiti Rehemanjiang[2], Ulrich Kuhl[1], and Hans-Jürgen Stöckmann[2] — [1]Université Côte d'Azur, CNRS, Institut de Physique de Nice (InPhyNi), 06108 Nice, France — [2]Fachbereich Physik der Philipps-Universität Marburg, D-35032 Marburg, Germany

Recently an experimental realization of a system with a symplectic symmetry $\mathcal{T}$, $\mathcal{T}^2=-1$, was demonstrated [1], showing for the first time, e.g., typical level repulsion of s^4 in accordance with the Gaussian Symplectic Ensemble (GSE). It is based on a division of the whole graph into two Gaussian unitary subsystems (GUE) being the complex conjugate of each other. The coupling between these is realized by a set of microwave bonds connecting them to each other. Choosing the coupling appropriately one can realize anti-unitary symmetries of type $\mathcal{T}^2=-1$, $\mathcal{T}^2=1$, or no symmetry at all as well as a transition between them.

We will present how this transition behaves in the experimentally relevant case of a minimal number of bonds. In order to see the convergence to the corresponding Wigner predictions we accompany the experimental works with numerical random matrix simulations [2]. It allows to investigate the transition from GSE via GUE to the Gaussian Orthogonal Ensemble (GOE) by varying a phase difference between the coupling bonds.

[1] A. Rehemanjiang et. al., *Phys. Rev. Lett.* **117**, 064101 (2016)
[2] A. Rehemanjiang et. al., *arXiv*:1708.06236 [quant-ph]

DY 23.7 Tue 11:45 EB 107

Universal symmetry classes in three-terminal mi-

crowave graphs — Angel M. Martínez-Argüello[1], •Aimaiti Rehemanjiang[2], Moises Martínez-Mares[3], J. Antonio Méndez-Bermúdez[1], Hans-Jürgen Stöckmann[2], and Ulrich Kuhl[2,4] — [1]Instituto de Física, Benemérita Universidad Autónoma de Puebla, Puebla, Mexico — [2]Fachbereich Physik der Philipps-Universität Marburg, Marburg, Germany — [3]Departamento de Física, Universidad Autónoma Metropolitana-Iztapalapa, Mexico City, Mexico — [4]Université Côte d'Azur, CNRS, Institut de Physique de Nice, Nice, France

In direct analogy between electrical conduction and transport through scattering devices [1], measurements of a classical analog of a quantum observable through three-terminal microwave graphs are performed. One of the ports is placed as input and a second one as output, while a third port is used as a probe. Exact analytical predictions show good agreement with the measurements in the presence of orthogonal and unitary symmetries, provided that the absorption and coupling strength to the graphs are taken into account. In addition, the symplectic symmetry was implemented using a recent realization of graphs with such a symmetry [2]. Notably, neither the power losses nor the coupling strengths spoil the signatures of the symplectic symmetry. This represents the first classical-transport experiment that mimics a spin 1/2 system.

[1] M. Büttiker, Phys. Rev. Lett. **57**, 1761 (1986).
[2] A. Rehemanjiang et al., Phys. Rev. Lett. **117**, 064101 (2016).

DY 23.8 Tue 12:00 EB 107

Bohmian trajectories for the half-line barrier — •Remy Dubertrand[1,2], Jeongbo Shim[2], and Ward Struyve[3] — [1]Institut für Theoretische Physik Universität Regensburg 93040 Regensburg, Germany — [2]Institut de Physique Nucleaire, Atomique et de Spectroscopie, CESAM, University of Liege, Bat. B15, B - 4000 Liege, Belgium — [3]Mathematisches Institut, Ludwig-Maximilians-Universität München, Theresienstr. 39, 80333 München, Germany

Bohmian trajectories are considered for a free particle that is scattered by a half-line barrier [1]. On the barrier, both Dirichlet and Neumann boundary conditions are considered. The half-line barrier yields one of the simplest cases of diffraction. Using the exact time-dependent propagator found by Schulman, the trajectories are computed numerically for different initial Gaussian wave packets. In particular, it is found that different boundary condition may lead to qualitatively different sets of trajectories. In the Dirichlet case, the particles tend to be more strongly repelled. The case of an incoming plane wave is also considered. The corresponding Bohmian trajectories are compared with the trajectories of an oil drop hopping on the surface of a vibrating bath.

[1] R. Dubertrand, J. Shim, W. Struyve, arxiv.1707.06173 (2017)