DY 41: Quantum Chaos

Time: Wednesday 15:00–17:45 Location: H48

Invited Talk DY 41.1 Wed 15:00 H48

Visualizing quantum chaos in four dimensions — •Arnd Bäcker — TU Dresden, Institut für Theoretische Physik and Center for Dynamics, Dresden — MPI für Physik komplexer Systeme, Dresden

As the simplest example of higher-dimensional systems with a mixed phase space we consider 4D maps. The global organization of regular tori is visualized using 3D phase-space slices [1, 3]. Representing regular and chaotic eigenstates in the 3D phase-space slice allows for comparing with classical structures to investigate the semiclassical eigenfunction hypothesis.

Such 4D maps can also be interpreted as two coupled 2D systems. If these two subsystems are strongly chaotic, we demonstrate that spectral statistics show a universal transition towards random matrix fluctuations for increasing interaction strength [2]. Moreover, entanglement in eigenstates, as measured by the von-Neumann entropy, shows a universal transition to nearly maximal entanglement.

[1] M. Richter, S. Lange, A. Bäcker, and R. Ketzmerick, *Visualization and comparison of classical structures and quantum states of four-dimensional maps*, Phys. Rev. E **89**, 022902 (2014).

[2] S. C. L. Srivastava, S. Tomsovic, A. Lakshminarayan, R. Ketzmerick, and A. Bäcker, *Universal scaling of spectral fluctuation transitions for interacting chaotic systems*, arXiv:1509.02329, Phys. Rev. Lett. in press.

[3] For videos of 3D phase space slices see:
`http://www.comp-phys.tu-dresden.de/supp/`

DY 41.2 Wed 15:30 H48

Interplay between chaos and indistinguishability in multiparticle scattering — •Juan-Diego Urbina[1], Jack Kuipers[1], Klaus Richter[1], Quirin Hummel[1], and Sho Matsumoto[2] — [1]Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany — [2]Graduate School of Science and Engineering, Kagoshima University, 1-21-35, Korimoto, Kagoshima, Japan

In this presentation we generalize the Hong-Ou-Mandel effect to the mesoscopic regime of complex scattering and to macroscopically occupied incoming wavepackets. This is achieved by a complete enumeration of all processes in terms of interfering many-body paths that allow us to study universal effects due to the interplay between instability of the single-particle classical motion and quantum indistinguishability.

We show how, in the limit of large particle number, one finds a mesoscopic version of the bosonic birthday paradox responsible for a sharp quantum-classical transition. Furthermore, under a scaling that defines the classical-quantum boundary we predict a macroscopic, experimentally accessible Hong-Ou-Mandel profile.

Our results are obtained by a combination of Random Matrix Theory and semiclassical methods, and can be extended to the quantum optics domain, and point towards a mesoscopic implementation of the boson sampling problem of current interest as a possible first realization of a quantum simulator for a certified hard problem.

DY 41.3 Wed 15:45 H48

Chaotic transport in resonance channels in 4D maps — •Franziska Onken[1,2], Steffen Lange[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

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. It is governed by families of elliptic and hyperbolic 1D-tori together with their stable and unstable manifolds. This provides a visualization of a turnstile in higher dimensions which allows for the escape from the channel.

DY 41.4 Wed 16:00 H48

Resonance-assisted tunneling in deformed optical microdisk cavities — •Julius Kullig and Jan Wiersig — ITP, Otto-von-Guericke-Universität Magdeburg, 39106 Magdeburg, Germany

In generic systems tunneling not only occurs at energy barriers but also between classically disjoint regions in phase space. Nonlinear resonance chains which arise generically from system perturbations drastically enhance the tunneling effect which is then called resonance-assisted tunneling (RAT). While RAT is well studied for kicked Hamiltonian systems and experimentally observed in microwave billiards its application to optical cavities is less investigated. But here a recent experiment by [Kwak et al., Sci. Rep. 2015] suggests a particular relevance. In our talk we use perturbative methods for RAT to predict quality factors and optical mode structures of deformed microdisk cavities.

DY 41.5 Wed 16:15 H48

Three-dimensional description of optical microcavities — •Jakob Kreismann and Martina Hentschel — TU Ilmenau, Ilmenau, Deutschland

Microcavity lasers made of deformed dielectric disk resonators such as the Limaçon-shaped cavity have attracted a lot of interest because they show directional light emission. Both ray optics and wave simulations for two-dimensional model systems confirm the support of whispering gallery-like modes with high quality factors while possessing directional light emission. In reality, however, these microcavities are three-dimensional objects with finite heights. Therefore we perform numerical simulations of the full three-dimensional system and investigate the influence of the cavity height on the resonance energies, their quality factors and far-field profiles. We discuss analogies of the structure between the two-dimensional and three-dimensional modes, and find a dependence on the ratio of the cavity height to the wavelength that can be quantified in terms of the effective refractive index model. The analysis of the three-dimensional far-field profiles reveals directional emission in azimuthal direction (i.e. in the plane of the resonator) as known from the two-dimensional case, and furthermore directional emission inclined to that plane as a truly three-dimensional effect. We use this new effect for a possible technical application, and design a sensor that can detect particles in the environment based on changes in the emission direction.

15 min. break

DY 41.6 Wed 16:45 H48

Triangular microlasers in the ray picture — •Pia Stockschläder and Martina Hentschel — Technische Universität Ilmenau, Institut für Physik, Ilmenau, Germany

We apply ray-optical methods to dielectric optical microcavities in the shape of triangles made of low refractive index material. Geometrical optics is extended by the inclusion of intensity amplification along the optical path to achieve a better description of active, lasing cavities. Far-field emission patterns of triangular cavities obtained in this way agree well with experimental results. We find ray trajectories that maximize the intensity inside the cavity to determine the far-field emission characteristics. As these maximum intensity orbits need not to be periodic we suggest that they provide a more general explanation for emission patterns of microlasers than single periodic orbits. We present results for triangles of different symmetry classes.

DY 41.7 Wed 17:00 H48

Phase-space localization of chaotic resonance states — •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 open quantum systems with escape a fundamental question concerns the phase-space localization of resonance states. For fully chaotic systems the resonance states are supported on a fractal set of classically trapped orbits. We investigate the possibility of quantum ergodicity, i.e. equidistribution of resonance states with respect to suitable classical densities on this fractal set. We observe remarkable deviations from naturally expected fractal densities on large scales and study their origin.

DY 41.8 Wed 17:15 H48

Experiments on microwave graphs with anti-unitary symmetry squaring to minus one — •Aimaiti Rehemanjiang[1], Markus Allgaier[2,1], Christopher Joyner[5], Sebastian Müller[3], Mar-

tin Sieber[3], Hans-Jürgen Stöckmann[1], and Ulrich Kuhl[4,1] — [1]Quantum chaos group, Fachbereich Physik der Philipps-Universität, Marburg, Germany — [2]Integrated Quantum Optics, Applied Physics, Universität Paderborn, Paderborn, Germany — [3]School of Mathematics, University of Bristol, Bristol, UK — [4]Laboratoire de Physique de la Matière Condensée, CNRS UMR 7336, Université Nice Sophia Antipolis, Nice, France — [5]School of Mathematical Sciences, Queen Mary University of London, London, UK

Following an idea by Joyner et al. [1] a microwave graph with antiunitary symmetry squaring to -1 has been realized. The Kramers doublets expected for such systems have been clearly identified and could be lifted by a perturbation which breaks this antiunitary symmetry. The found spectral level spacings distribution of these Kramers doublets is in agreement with the predictions from the Gaussian symplectic ensemble, expected for chaotic systems with such an antiunitary symmetry.

[1] C. Joyner, S. Müller, M. Sieber, EPL, 107 (2014) 50004

DY 41.9 Wed 17:30 H48

A new type of PT-symmetric random matrix ensembles

— •Steve Mudute-Ndumbe, Eva-Maria Graefe, and Matthew Taylor — Imperial College London, London, United Kingdom

In this talk I will introduce two new random matrix ensembles which can potentially be used to model non-Hermitian PT-symmetric quantum systems, an area of quantum mechanics which has attracted a considerable amount of attention recently. The new ensembles consist of matrices which are Hermitian with respect to the split-complex and split-quaternionic number systems. The eigenvalues of these matrices are either real or come in complex conjugate pairs. I will present some analytical and numerical results on their spectral statistics, focusing in particular on the spectral fluctuations, in the 2×2 and general $N \times N$ matrix size cases.