TT 44: Quantum Chaos (joint session DY/TT)

Time: Wednesday 15:00–19:00 Location: HÜL 186

Invited Talk TT 44.1 Wed 15:00 HÜL 186

Supersymmetric Polarization Anomaly in Photonic Discrete-Time Quantum Walks — •Sonja Barkhofen[1], Lennart Lorz[1], Thomas Nitsche[1], Christine Silberhorn[1], and Henning Schomerus[2] — [1]Applied Physics, University of Paderborn, Warburger Strasse 100, 33098 Paderborn, Germany — [2]Department of Physics, Lancaster University, Lancaster LA1 4YB, United Kingdom

Quantum anomalies lead to finite expectation values that defy the apparent symmetries of a system. These anomalies are at the heart of topological effects in electronic, photonic, and atomic systems, where they result in a unique response to external fields but generally escape a more direct observation. Here, we implement an optical-network realization of a discrete-time quantum walk, where such an anomaly can be observed directly in the unique circular polarization of a topological midgap state. We base the system on a single-step protocol overcoming the experimental infeasibility of earlier multistep protocols. The evolution combines a chiral symmetry with a previously unexplored unitary version of supersymmetry. Having experimental access to the position and the coin state of the walker, we perform a full polarization tomography and provide evidence for the predicted anomaly of the midgap states. This approach opens the prospect to dynamically distill topological states for quantum information applications.

TT 44.2 Wed 15:30 HÜL 186

Corrected perturbation theory for transverse-electric whispering-gallery modes in deformed microdisks — •Manuel Badel and Jan Wiersig — Postfach 4120, D-39016 Magdeburg, Germany

The perturbation theory by Ge et al. [Phys. Rev. A 87, 023833 (2013)] for transverse-electric polarized modes in weakly deformed microdisks omits terms related to the variation of the normal derivative of the magnetic field along the boundary. We show that these terms are necessary to accurately describe microdisks with a strongly winding boundary. In particular, it is demonstrated that the corrected perturbation theory allows one to describe the counterintuitive phenomenon of Q-factor enhancement due to weak boundary deformation, examplified by the microflower cavity. Good agreement of the corrected perturbation theory with full numerical results is observed.

TT 44.3 Wed 15:45 HÜL 186

Controlling chaos in the quantum regime using adaptive measurements — •Jessica Eastman[1,2,3], Stuart Szigeti[1], Joseph Hope[1], and André Carvalho[3] — [1]Department of Quantum Science, Research School of Physics and Engineering, The Australian National University, Canberra, ACT 2601, Australia — [2]Centre for Quantum Computation and Communication Technology (Australian Research Council), Griffith University, Brisbane, Queensland 4111, Australia — [3]Centre for Quantum Dynamics, Griffith University, Brisbane, Queensland 4111, Australia

The continuous monitoring of a quantum system strongly influences the emergence of chaotic dynamics near the transition from the quantum regime to the classical regime. Here we present a feedback control scheme that uses adaptive measurement techniques to control the degree of chaos in the driven-damped quantum Duffing oscillator. This control relies purely on the measurement backaction on the system, making it a uniquely quantum control, and is only possible due to the sensitivity of chaos to measurement. We quantify the effectiveness of our control by numerically computing the quantum Lyapunov exponent over a wide range of parameters. We demonstrate that adaptive measurement techniques can control the onset of chaos in the system, pushing the quantum-classical boundary further into the quantum regime.

TT 44.4 Wed 16:00 HÜL 186

Microstar cavities: An alternative concept for the confinement of light — •Julius Kullig[1], Xuefeng Jiang[2], Lan Yang[2], and Jan Wiersig[1] — [1]Institut für Physik, Otto-von-Guericke Universität Magdeburg, Magdeburg, Germany — [2]Department of Electrical and Systems Engineering, Washington University in St. Louis, St. Louis, USA

We report on a novel concept to confine light in a microcavity. In contrast to traditional approaches we exploit neither total internal reflection nor a photonic band gap. Our approach is rather based on the perfect transmission of light at Brewster's angle. Thus, in a properly designed star-shaped cavity light rays can sequentially leave and reenter the cavity along a periodic orbit without loss of intensity. Accordingly, in the wave dynamics long-lived optical modes arise with fascinating and unique properties.

TT 44.5 Wed 16:15 HÜL 186

Investigations on the spectral density of kicked spin chains — •Felix Meier, Daniel Waltner, Petr Braun, and Thomas Guhr — Fakultät für Physik, Universität Duisburg-Essen, Duisburg, Deutschland

We study the semiclassical description of locally interacting spin chains whose individual constituents are identical to the kicked-top model. The magnetic field inducing the periodically applied kicks is chosen so that the model is quantum mechanically non-integrable for all possible spin representations. The classical analog of the spin chain is a collection of coupled Bloch vectors, whose dynamics is described stroboscopically. The corresponding classical phase space features highly mixed behavior with regular and chaotic motion occuring simultaneously. We investigate the structure of the quantum spectral density for different particle numbers and system parameters, which send the classical analog through a number of bifurcations.

TT 44.6 Wed 16:30 HÜL 186

Many-Body Densities of States on Quantum Graphs — •Adrian Seith[1], Gregor Tanner[2], Stephen Creagh[2], Klaus Richter[1], and Juan-Diego Urbina[1] — [1]Institut für Theoretische Physik, Universität Regensburg, Universitätsstraße 31 D-93053 Regensburg — [2]School of Mathematical Sciences, University of Nottingham, University Park, Nottingham, NG7 2RD, UK

We study the bulk density of states in non-interacting many-body systems on a quantum graph, a one-dimensional network of connected bonds on which the wave function is a solution of the one-dimensional Schrödinger equation.

In [1], Kottos & Smilansky derived a trace formula for the spectrum of a one-particle quantum graph using a secular equation and a transfer operator that describes the dynamics of the system. In [2], Bolte & Kerner show that the DOS of a many-body quantum graph follows an asymptotic Weyl law. We derive an explicit expression of the many-particle DOS on quantum graphs for distinguishable and indistinguishable particles and extend Smilansky's transfer operator approach to many-body systems using Bogomolny's formalism [3] so that we can give a geometric interpretation of many-body quantum graphs and the principle of indistinguishability and pave the way to include interaction effects.

[1] T. Kottos, U. Smilansky. Annals of Physics, Vol. 274 (1999)
[2] J. Bolte, J. Kerner. Journal of Mathematical Physics 55, (2014)
[3] E. B. Bogomolny. Nonlinearity, Vol. 5 (1992)

TT 44.7 Wed 16:45 HÜL 186

New insights on the semiclassical study of many-body interference in Fermionic Fock space: a path integral approach — •Wolfgang Hogger, Juan-Diego Urbina, Falk Bruckmann, and Klaus Richter — Universität Regensburg

A long standing goal of quantum chaos is to establish the classical limit of Fermionic fields and to follow the corresponding semiclassical program. Following Gutzwiller, we propose to apply the stationary phase approximation to the coherent state path integral for bosons on a lattice and transforming a Fermionic system into the latter by subsequent use of Jordan-Wigner transformation and Schwinger-boson mapping. However, it was shown by Wilson and Galitzki in PRL 106, 110401 (2011) how the coherent state path integral breaks down for the Bose-Hubbard model and simple spin systems. Since the issues with the partition function path integral for the aforementioned systems were solved by Bruckmann and Urbina in arXiv:1807.10462v1 through dualization (a known method from lattice quantum field theories), the correct perturbative expansion is now correctly reproduced and one can obtain a path integral for the propagator as well. As a second key ingredient, thanks to a novel transformation in the spirit of Jordan-Wigner providing an exact map from many Fermionic degrees of freedom to a single large spin, we now obtain also a well-defined classical limit. Combining these two insights, a semi-classical theory of generic Fermi-Hubbard models is finally constructed and applied to some simple examples.

15 min. break.

TT 44.8 Wed 17:15 HÜL 186

Geometry of complex instability in four-dimensional symplectic maps — •Jonas Stöber[1,2] and Arnd Bäcker[1,2] — [1]TU Dresden, Institut für Theoretische Physik — [2]MPI für Physik komplexer Systeme, Dresden

In four-dimensional symplectic maps complex instability of periodic orbits is possible, which cannot occur for the two-dimensional case. We investigate the transition from stable to complex unstable dynamics of a fixed point under parameter variation. The change in the geometry of regular structures is visualized using three-dimensional phase-space slices and in frequency space using the example of two coupled standard maps. The chaotic dynamics is studied using escape time plots and two-dimensional invariant manifolds associated with the complex unstable fixed point. Based on a normal-form description, we investigate the underlying transport mechanism by visualizing the escape paths and the long-time confinement in the surrounding of the complex unstable fixed point. Consequences for the quantum wave-packet dynamics are illustrated.

TT 44.9 Wed 17:30 HÜL 186

Quantum signatures of separatrix crossing: self-trapping in high dimensional Bose-Hubbard systems — •Mathias Steinhuber[1], Steven Tomsovic[2], Remy Dubertrand[1], Klaus Richter[1], and Juan-Diego Urbina[1] — [1]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany — [2]Department of Physics and Astronomy, Washington State University, Pullman, Washington 99164-2814, USA

We generalize the concept and phenomenology of self-trapping in the integrable Bose-Hubbard dimer into systems with non-integrable mean-field dynamics by relating it with crossing of separatrices. To this end, we construct a mapping of site-periodic solutions to find a sub-manifold of integrable dynamics in the non-integrable phase space. This new and powerful concept allows us to analytically explain the numerical observation of a massive transition in the stability properties of mean-field solutions found by Tomsovic in [1]. We also show how this mapping has extensions and generalizations to higher dimensions, opening a door for analytical understanding beyond state of the art numerics, and obtain the Lyapunov spectra of site-periodic fix points, their stabilities and bifurcations. Last we show some quantum signatures of these morphology changes in the classical phases space focusing primarily on the self-trapping transition.

[1] Tomsovic, S. Complex saddle trajectories for multidimensional quantum wave packet and coherent state propagation: application to a many-body system. Phys. Rev. E 98, 023301 (2 Aug. 2018)

TT 44.10 Wed 17:45 HÜL 186

What is the structure of chaotic resonance eigenfunctions? — •Roland Ketzmerick[1,2], Konstantin Clauss[1], Felix Fritzsch[1], and Arnd Bäcker[1,2] — [1]TU Dresden, Institut für Theoretische Physik — [2]MPI für Physik komplexer Systeme, Dresden

While chaotic eigenfunctions in closed systems are uniformly distributed according to the quantum ergodicity theorem, they show fractal structures in systems with escape. This structure depends crucially on the decay rate of the resonance eigenfunction. It is semiclassically quite well understood for quantum maps with full [1] and partial [2] escape. Here we present the extension to billiard systems, in particular the famous three-disk system (full escape) and the dielectric limaçon billiard relevant for optical microcavities (partial escape).

[1] K. Clauß, M. J. Körber, A. Bäcker, and R. Ketzmerick, Phys. Rev. Lett. **121**, 074101 (2018).

[2] K. Clauß, E. G. Altmann, A. Bäcker, and R. Ketzmerick, Phys. Rev. E **100**, 052205 (2019).

TT 44.11 Wed 18:00 HÜL 186

A PT-symmetric kicked top — Steve Mudute-Ndumbe and •Eva-Maria Graefe — Imperial College London, UK

A PT-symmetric version of the kicked top is introduced to study the interplay of quantum chaos with loss and gain. The classical dynamics arising from the quantum dynamics of the angular momentum expectation values are derived and analysed in some detail. Further, the statistics of the (complex) eigenvalues of the quantum system are investigated.

TT 44.12 Wed 18:15 HÜL 186

Towards universal Hong-Ou-Mandel correlations in topological insulators — •Andreas Bereczuk[1], Juan Diego Urbina[1], Barbara Dietz[2], Jack Kuipers[3], Cosimo Gorini[1], and Klaus Richter[1] — [1]Institut of Theoretical Physics, University Regensburg, Germany — [2]School of Physical Science and Technology, Lanzhou University, China — [3]Department of Biosystems Science and Engineering (BSSE), ETH Zurich, Switzerland

The indistinguishable-distinguishable transition for the transmission probability for two fermions propagating through a quantum point contact is a known manifestation of the celebrated Hong-Ou-Mandel (HOM) effect [1] in electron quantum optics [2]. As shown in [3], universal HOM correlations are expected by substituting the quantum point contact by a chaotic cavity in a mesoscopic regime [3] where universal correlations of the scattering matrix entries at different energies enter. We present here a consistent semiclassical, numerical and Random Matrix Theory (RMT) analysis of this correlators together we a progress report on its experimental realization in a microwave billard. With this results at hand, we propose a HOM setup with cavities as complex beam splitters and edge states instead of waveguides to observe universal HOM correlations in a topological insulators (TI).

[1] C. K. Hong, Z. Y. Ou and L. Mandel, Phys. Rev. Lett. 59, 2044 (1987)

[2] E. Bocquillon et al., Annalen der Physik 526, 1 (2014)

[3] J. D. Urbina et al., Phys. Rev. Lett. 116, 100401 (2016)

TT 44.13 Wed 18:30 HÜL 186

The Conditioned Real Ginibre Ensemble and PT-Symmetric Quantum Chaos — •Simon Malzard[1], Steve Mudute-Ndumbe[1], Roman Riser[2], Joshua Feinburg[2], and Eva-Maria Graefe[1] — [1]Imperial College London, London, UK — [2]University of Haifa, Haifa, Israel

In Hermitian systems the universality of spectral fluctuations described by the standard Gaussian ensembles is one of the most pronounced fingerprints of chaos in a quantum system. With the recent intense interest in non-Hermitian PT-symmetric systems, it is a natural question whether there are PT-symmetric random matrix ensembles yielding similar universality classes. One candidate for PT-symmetric systems with P^2=1 and T^2=1 which display quantum chaos is the real Ginibre ensemble. Eigenvalues of real Ginibre matrices are real or occur in complex conjugate pairs. The spectral properties of the real Ginibre matrices depend crucially on the number of real eigenvalues. Hence, when studying the eigenvalue distributions and level spacings of PT-symmetric quantum chaotic systems, one should make comparisons to an ensemble of real Ginibre matrices conditioned to have the corresponding number of real eigenvalues. Here we present a numerical method to produce samples of real Ginibre matrices conditioned to have a particular number of real eigenvalues.

TT 44.14 Wed 18:45 HÜL 186

Rate of decoherence and entanglement growth in coupled kicked rotors — •Sanku Paul[1] and Arnd Bäcker[2,1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden 01187, Germany — [2]Technische Universität Dresden, Institut für Theoretische Physik, Dresden 01069, Germany

The classical-quantum correspondence of a pair of coupled kicked rotors is investigated. In this interacting system, one rotor acts as an environment to the other. This leads to the emergence of decoherence with classical-like behavior at large times. This classical-like behavior is characterized by normal diffusion in energy space and interestingly, it is preceded by an intermediate dynamical localization for weak interactions. It is observed that these different rates of energy diffusion are associated with different regimes of decay of coherence, in particular showing exponential and power-law behavior. We show that the observed decoherence is related to distinct rates of entanglement entropy growth between the rotors which is described by an initial power-law followed by logarithmic growth.