Symposium on
"Quantum Chaos, Billards, RMT and more"
in honor of Hans-Jürgen Stöckmann on his 70th birthday

Centro Internacional de Ciencias A.C.
Cuernavaca, Mexico
August 31 – September 4, 2015

Status: September 4, 2015

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Henning Schomerus	Lancaster University
Thomas Seligman	ICF-UNAM
Leszek Sirko	Institute of Physics, Polish Academy of Sciences
Thomas Stegmann	ICF-UNAM
Hans-Jürgen Stöckmann	Universität Marburg
Jacobus Verbaarschot	Stony Brook University
Manan Vyas	ICF-UNAM
Tobias Weich	Universität Paderborn

	Monday	Tuesday	Wednesday	Thursday	Friday
10:00 am	Schomerus	Leyvraz	Gorin	Franco	Gros
10:30 am					
11:00 am	Coffee Break	Coffee Break	Coffee Break	Brandstötter	Coffee Break
11:30 am	Kottos	Sirko	Stöckmann		Kuhl
12:00 am				Coffee Break	
12:30 am	Dietz	Barkhofen	Vyas	Verbaarschot	Benet
1:00 pm					
1:30 pm	Lunch	Lunch	Lunch	Sadurní	Lunch
2:00 pm					
2:30 pm				Birthday party at the Cave	
3:00 pm	Izrailev	Weich	Heller		Pineda
3:30 pm					
4:00 pm	Coffee Break	Coffee Break	Méndez		Coffee Break
4:30 pm	Stegmann	Chabanov			Báez
5:00 pm			Coffee Break		
5:30 pm	Jung	Poster	Colloquium of the Physics Institute		Luna-Acosta
6:00 pm					
6:30 pm					
7:00 pm					
7:30 pm		Reception at the Guest House			
8:00 pm					
8:30 pm					
9:00 pm					

Monday, August 31, 10:00 – 11:00
Chair: Ulrich Kuhl

Henning Schomerus

Lancaster University

Symmetry and topology in photonic systems

Topological photonic systems generate robust modes whose properties are well controlled. A difference to the original electronic context, from which these concepts are borrowed, are photon creation and annihilation processes, which induce a new class of exploitable symmetries but also serve as an extra source of noise. I illustrate these concepts for a few examples: PT-symmetric lasers [1], selective amplification of a topologically induced defect mode [2], and emerging charge-conjugation symmetry in coupled resonator optical waveguides [3].

[1] H.Schomerus, Quantum Noise and Self-Sustained Radiation of PT-Symmetric Systems, Phys. Rev. Lett. 104, 233601 (2010).

[2] C. Poli, M. Bellec, U.Kuhl, F. Mortessagne, H. Schomerus, Selective enhancement of topologically induced interface states in a dielectric resonator chain, Nat. Commun. 6, 6710 (2015).

[3] S. Malzard, C. Poli, H. Schomerus, Topologically protected defect states in open photonic systems with non-hermitian charge-conjugation and parity-time symmetry, arxiv:1508.03985

Monday, August 31, 11:30 – 12:30
Chair: Ulrich Kuhl

Tsampikos Kottos

Wesleyan University

Non-Hermitian Optical Structures with Losses

In recent years non-hermitian optics has attracted a lot of attention. One of the goals of this subfield is to introduce and tailor losses in optical structures in order to come up with designs that show novel transport features like asymmetric transport, switching, invisibility etc. We will discuss some of these set-ups and illuminate on the dual role of loss as a source of absorption and enhanced reflection due to impedance mismatching. Applications along these lines will be discussed.

Monday, August 31, 12:30 – 13:30
Chair: Ulrich Kuhl

Barbara Dietz

Technische Universität Darmstadt

Experiments with Superconducting Microwave Resonators Emulating Artificial Graphene and Fullerene C60

We investigated spectral properties and the distributions of the ratios of consecutive spacings between adjacent eigenfrequencies of a rectangular and a Africa-shaped superconducting microwave resonator containing circular scatterers arranged on a triangular grid, so-called Dirac billiards. The high-precision measurements allowed the determination of all 1651 and 1823 eigenfrequencies, respectively, in the first two bands. The resonance densities are similar to that of graphene and exhibit two sharp peaks at the van Hove singularities. The latter divide the associated band into regions where the system is governed by the non-relativistic Schrödinger equation of the quantum billiard and the Dirac equation of the graphene billiard of corresponding shape, respectively. Furthermore, even in the vicinity of the van Hove singularities, the ratio distributions, which have the great advantage that no unfolding is necessary, provide a useful statistical measure for the spectral fluctuation properties. In the second part of my talk I will report on experiments with a superconducting microwave resonator that had the geometric structure of the C_{60} fullerene molecule. Firstly, we studied the exceptional spectral properties emerging from the symmetries of the icosahedral structure of the carbon lattice. Secondly, we determined the number of zero modes with eigenvalues at the Dirac point, existent in the band structure due to the hexagonal arrangements of the carbon atoms, to verify the Atiyah-Singer index theorem, which relates it to the topology of the curved carbon lattice.

Supported by the DFG within the Collaborative Research Center CRC634

Monday, August 31, 15:00 – 16:00
Chair: Barbara Dietz

F. Izrailev, F. Borgonovi, F. Mattiotti

Benemérita Universidad Autónoma de Puebla

Quantum chaos and thermalization in the TBRI model of interacting bosons.

We study the onset of chaos and thermalization in the Two-Body Random Interaction (TBRI) model in dependence on the strength of interaction between bosons. We focus on the dilute limit case for which the number N of bosons is less than the number M of single-particles levels. We show that our approach developed earlier for interacting Fermi-particles, also works well for interacting bosons. Specifically, we demonstrate that with an increase of the interaction the many-body states begin to fill the energy shell that can be treated as the delocalization in the Fock space. We show that when the eigenstates are chaotic, one can speak of thermalization in an isolated system in terms of standard observables, such as the occupation number distribution. The numerical data are complemented by analytical estimates.

Monday, August 31, 16:30 – 17:30
Chair: Barbara Dietz

Thomas Stegmann

ICF-UNAM

Edge magnetotransport in 2D electron systems & general relativity in deformed graphene

In the first part of this talk, we discuss the current flow along the boundary of 2D electron systems (GaAs and graphene) in a perpendicular magnetic field. The regime of classical cyclotron motion and the quantum Hall effect are intermixed by suitable system parameters. We observe anomalous resistance oscillations, which are explained by the interference of the occupied edge channels causing beatings in the resistance [1,2].

In the second part of this talk, we study transport in deformed graphene ribbons. We show that the local current flow is compatible with the geodesics from general relativity and discuss the effect of the curvature and the pseudomagnetic field [3].

[1] T. Stegmann, D. E. Wolf, A. Lorke: Magnetotransport along a boundary: from coherent electron focusing to edge channel transport, New. J. Phys. 15:113047 (2013)

[2] T. Stegmann, A. Lorke: Edge magnetotransport in graphene: A combined analytical and numerical study, Ann. Phys. (Berlin), (2015, page number and issue not yet assigned), DOI: 10.1002/andp.201500124

[3] T. Stegmann, N. Szpak: Transport phenomena in deformed graphene: Magnetic field versus curvature, in preparation

Monday, August 31, 17:30 – 18:30
Chair: Barbara Dietz

Christof Jung

ICF-UNAM

The perturbation of partial integrability

We study a typical perturbation scenario of a partially integrable Hamiltonian three degrees of freedom system. It is the motion of a charged particle in a perturbed magnetic dipole field, the so called Störmer problem. The partially integrable and reducible case is a pure dipole field with its rotational symmetry. The perturbation consists in the addition of other multipole components which destroy the rotational symmetry. This example demonstrates how we can understand the 4 dimensional Poincare map of a three degrees of freedom system close to partial integrability as a stack of reduced 2 dimensional Poincare maps and how very naturally a normally hyperbolic invariant manifold of dimension 2 takes over the role of the most important element of the chaotic invariant set in the map.

Francois Leyvraz

ICF-UNAM

Temperature gradients in equilibrium: Small systems at constant energy

Michał Ławniczak, Małgorzata Białous, Vitalii Yunko, Szymon Bauch, Leszek Sirko

Institute of Physics, Polish Academy of Sciences

The enhancement factor in a transient region between regular and chaotic dynamics

We present the results of an experimental study of the elastic enhancement factor W for microwave rough and rectangular cavities simulating, respectively, a two-dimensional chaotic quantum billiard and a quantum billiard in a transient region between regular and chaotic dynamics. The analogy between microwave cavities and quantum billiards is based upon the equivalency of the Helmholtz equation describing the microwave cavities [1] and the Schroedinger equation describing quantum systems possessing time reversal symmetry. We show that the elastic enhancement factor for the rectangular cavity lies below the theoretical value $W = 3$ predicted for integrable systems and it is significantly higher than the one obtained for the rough cavity [2]. The departure of the rectangular system from the integrable one due to presence of antennas acting as scatterers is characterised by the parameter of chaoticity $\kappa = 2.8$. The results obtained for the microwave rough cavity are smaller than those obtained within the framework of random matrix theory, and they lie between them and those predicted within a recently introduced model of the two-channel coupling [3].

We also discuss the elastic enhancement factor W in the case of microwave networks and quantum graphs possessing time reversal symmetry and the ones with broken time reversal symmetry [4-6]. Our experimental results suggest that the enhancement factor can be used as a measure of internal chaos that can be especially useful for systems with significant absorption or openness.

This work was partially supported by the EU 7th Framework Programme under the CAPACITIES project REGPOT-CT-2013-316014 (EAgLE) and by the Ministry of Science and Higher Education grants N N202 130239 and UMO-2013/09/D/ST2/03727.

[1] H. J. Stoeckmann, J. Stein, Phys. Rev. Lett. **64**, 2215 (1990)

[2] M. Ławniczak, M. Białous, V. Yunko, S. Bauch, L. Sirko, Phys. Rev. E **91**, 032925 (2015)

[3] V. V. Sokolov, O. V. Zhirov, Phys. Rev. E **91**, 052917 (2015)

[4] O. Hul, S. Bauch, P. Pakoński, N. Savytskyy, K. Zyczkowski, L. Sirko, Phys. Rev. E **69**, 056205 (2004)

[5] M. Ławniczak, S. Bauch, O. Hul, L. Sirko, Phys. Rev. E **81**, 046204 (2010)

[6] O. Hul, M. Ławniczak, S. Bauch, A. Sawicki, M. Kuś, L. Sirko, Phys. Rev. Lett **109**, 040402 (2012)

Tuesday, September 01, 12:30 – 13:30
Chair: Thomas Seligman

Sonja Barkhofen

Universität Paderborn

Quantum Walk Coherences on a dynamical Percolation Graph

Photonic quantum walk systems can be considered as a standard model to describe the dynamics of quantum particles in a discretized environment and serve as a simulator for complex quantum systems, which are not as readily accessible. However, their experimental realization requires setups with increasing complexity in terms of number of modes and control of the system parameters. A key element for a versatile simulator is the ability to control the quantum-coin, which is the main entity responsible for the evolution of the quantum walk. Breaking links in the underlying graph structures leads to the concept of percolation, addressed in recent theoretical studies. In a generalization the graph topology can even change in time, modelling a randomly evolving, fluctuating medium. Yet, the implementation of dynamically changing graphs poses severe challenges. Here, we present an experiment with precise dynamical control of the underlying graph structure, facilitating the blending of percolation with a genuine quantum process while exploiting the high intrinsic coherence and versatility of a time-multiplexed quantum walk architecture. The observation of clear non-Markovian signatures in the coin space testifies the high coherence of the implementation and the extraordinary control of all system parameters. The robustness and versatility of our scheme allows for detailed experimental studies of transport phenomena with a resource-efficient setup. Our work is the proof-of-principle experiment of a quantum walk on a dynamical percolation graph, paving the way towards complex simulation of quantum transport in random media.

Tuesday, September 01, 15:00 – 16:00
Chair: Thomas Stegmann

Tobias Weich, Sonja Barkhofen

Universität Paderborn

Semi-classical distributions for open chaotic quantum systems

Semi-classical zeta functions and cycle expansion are well known to be efficient tools for the calculation of quantum resonances in open chaotic systems, such as n-disk systems. In particular in the high energy regime the semi-classical calculation of resonances via zeta function becomes several orders of magnitudes faster compared to a full quantum mechanical calculation of the scattering matrices. The drawback is, however, that ordinary zeta functions only give information about the resonance location while the S-matrix calculus also yields the associated scattering states.

In this talk we will introduce a weighted version of semi classical zeta functions. Using residue formulas we can associate to each resonance a semi classical distribution. We will furthermore compare these semi classical distributions to phase space distributions of the quantum scattering states for the three disk system.

Tuesday, September 01, 16:30 – 17:30
Chair: Thomas Stegmann

A. A. Chabanov, A. Pena, A. Girschik, F. Libisch, S. Rotter

University of Texas at San Antonio

The quasi-single-channel regime of transport through random media

The propagation of light through disordered media can be described by way of transmission channels, which connect incoming and outgoing external propagating waves. Although the detailed structure of a disordered sample can generally not be fully specified, these transmission channels can nonetheless be successfully controlled and used for focusing and imaging light through random media. In the talk we will discuss statistics of transport in the regime when the number of active transmission channels is reduced down to 1, due to photon localization. Both steady-state and dynamic aspects of wave transport in this quasi-single-channel regime will be considered.

Tuesday, September 01, 17:30 – 20:00

Poster Session

Wednesday, September 02, 10:00 – 11:00
Chair: Henning Schomerus

Thomas Gorin

Universidad de Guadalajara

Improving coherence with nested environments

I will discuss the decoherence in a central system coupled by dephasing to a "near" environment which in turn is coupled to another "far" environment. It is shown that increasing the coupling between near and far environment, the decoherence in the central system becomes slower. Modeling the two environments by random matrix theory and applying the Born-Markov approximation to the coupling between them, we obtain an analytical expression for the decoherence in the central system.

Wednesday, September 02, 11:30 – 12:30
Chair: Henning Schomerus

Hans-Jürgen Stöckmann

Universität Marburg

Spectral properties of microwave graphs with adsorption

Wednesday, September 02, 12:30 – 13:30
Chair: Henning Schomerus

Manan Vyas

ICF-UNAM

Quantum efficiencies in disordered networks

Wednesday, September 02, 15:00 – 16:00
Chair: Jean-Baptiste Gros

Eric Heller

Harvard University

Branched Flow and Freak Waves are Popping up All Over

Wednesday, September 02, 16:00 – 17:00
Chair: Jean-Baptiste Gros

Raphael Méndez

ICF-UNAM

Wave Transport Through Elastic Thin Plates

A panorama about the recent experimental results on vibrating plates in the high-frequency regime is given. We first show that neither dephasing nor absorption play a significant role in the transport of flexural vibrations through a plate with chaotic shape. Thus the fluctuations of the mechanical transmittance are correctly described by the random matrix theory at zero temperature. Secondly, the effect of the reflection symmetry on the wave transport was studied; preliminary experimental results are given. The effect of a non-symmetric coupling in a symmetric cavity, called external mixing in the nuclear physics jargon, was also investigated. Again the random matrices correctly predict the distribution of the flexural transmittance.

Wednesday, September 02, 17:30 – 18:30

Colloquium of the Physics Institute

Jacobus Verbaarschot

Stony Brook University

Random Matrix Theory and Universal Spectral Behavior

In 1951 Wigner introduced Random Matrix Theory to describe the spectral fluctuations of nuclei. Since then Random Matrix theory has been applied to virtually all fields of physics ranging from atomic physics and information theory to nuclear and particle physics.

In this colloquium, we will review its main applications and discuss the origin of universal behavior in spectra. It will be related to the separation of scales of the quantu and classical contributions to the spectral density which can also be understood in terms of massless excitations that arise as a consequence of spontaneous symmetry breaking.

Thursday, September 03, 10:00 – 11:00
Chair: Sonja Barkhofen

John Alexander Franco

ICF-UNAM

In-plane vibrations of a elastic plate: plane wave expansion modelling and experiment

Theoretical and experimental results for in-plane vibrations of a uniform rectangular plate with free boundary conditions are shown. The agreement between theory and experiment is excellent for the lower 95 modes covering a very wide frequency range from DC to 20 kHz.

Thursday, September 03, 11:00 – 12:00
Chair: Sonja Barkhofen

Andre Brandstötter

Technische Universität Wien

New insights on scattering through disordered and non-Hermitian media

In all of the diverse areas of science where waves play an important role, one of the most fundamental solutions of the corresponding wave equation is a stationary wave with constant intensity. The most familiar example is that of a plane wave propagating in free space. In the presence of any Hermitian potential, a wave's constant intensity is, however, immediately destroyed due to scattering. Here we show that this fundamental restriction is conveniently lifted when working with non-Hermitian potentials. In particular, we present a whole new class of waves that have constant intensity in the presence of linear as well as of nonlinear inhomogeneous media with gain and loss.

As has been demonstrated in the context of mesoscopic electron transport, waves travelling through a correlated disorder potential form distinct branching channels instead of spreading out smoothly [1]. As we show through detailed numerical calculations, transferring this phenomenon to optics opens up the way to exert direct control of branched flow. Specifically, we present a method based on wavefront shaping techniques [2] to select only specific branches out of the overall branched flow pattern. This approach can be used to steer light through a disordered system to specific targets along highly focused beams that would usually diffract in the same medium.

[1] Nature 410, 183-186 (2001)

[2] Nature Photonics 6, 283-292 (2012)

Thursday, September 03, 12:30 – 13:30
Chair: Thomas Gorin

<u>Jacobus Verbaarschot</u>

Stony Brook University

Bosonic Random Matrix Partition Functions

In the supersymmetric formulation of random matrix theory universality of spectral correlations as well as of other observables arises due to the scale separation that takes place as as consequence of spontaneous symmetry breaking. However, the Mermin-Wagner-Coleman theorem states that continuous symmetries cannot be broken spontaneously in two or less dimensions, and one may wonder if random matrix universality still applies in these cases. It has been suggested in the literature though, that this theorem does not apply to noncompact symmetries. Since the spontaneous broken symmetry of bosonic random matrix partition functions is noncompact, this may explain the observed spectral universality in two or fewer dimensions. This is the motivation to study the difference between the properties of fermonic and bosonic partition functions. We will construct two examples where symmetries are broken spontaneously for the bosonic partition function but not for the fermonic one with the same values of the physical parameters.

Thursday, September 03, 13:30 – 14:30
Chair: Thomas Gorin

<u>Emerson Sadurní</u>

Benemérita Universidad Autónoma de Puebla

Spectral design in bent waveguides

Friday, September 04, 10:00 – 11:00
Chair: John Alexander Franco

Jean-Baptiste Gros

Université de Nice

Flexural edge waves in elastic plates with free edges

Friday, September 04, 11:30 – 12:30
Chair: John Alexander Franco

Ulrich Kuhl

Université de Nice

Dynamical tunneling in closed and open microwave cavities

Friday, September 04, 12:30 – 13:30
Chair: John Alexander Franco

Luis Benet

ICF-UNAM

Probing two-particle exchange processes in two-mode Bose-Einstein condensates

We study the fidelity decay and its freeze for an initial coherent state of two-mode Bose-Einstein condensates in the Fock regime, considering a Bose-Hubbard model that includes two-particle tunneling terms. By using linear-response theory we find scaling properties of the fidelity as a function of the particle number that prove the existence of two-particle mode-exchange when a non-degeneracy condition is fulfilled. Tuning the energy difference of the two modes serves to distinguish the presence of two-particle mode-exchange terms through the appearance of certain singularities. Numerical results confirm our findings. This is joint work with Diego Espitia and Daniel Sahagún.

Friday, September 04, 15:00 – 16:00
Chair: Rafael Méndez

Carlos Pineda

Universidad Nacional Autónoma de México

Measuring and using non-markovianity

We construct measures for the non-Markovianity of quantum evolution with a physically meaningful interpretation. We first provide a general setting in the framework of channel capacities and propose two families of meaningful quantitative measures, based on the largest revival of a channel capacity, avoiding some drawbacks of other non-Markovianity measures. We relate the proposed measures to the task of information screening. This shows that the non-Markovianity of a quantum process may be used as a resource. Under these considerations, we analyze two paradigmatic examples, a qubit in a quantum environment with classically mixed dynamics and the Jaynes-Cummings model.

Friday, September 04, 16:30 – 17:30
Chair: Rafael Méndez

Gabriela Báez

Universidad Autónoma Metropolitana-Azcapotzalco

Mechanical Bloch oscillations

Bloch oscillations appear when an static electric field is applied to a crystal. In this work we show that Bloch oscillations are also present in mechanical waves when a periodic structure is modified introducing the mechanical analog of static electric field. A wave packet is created in a beam, in which the chirped heterostructure was machined, and its dynamics is measured. Within the structure the wave packet shows oscillations with a period fixed by the mechanical parameter analog to the electric field.

Friday, September 04, 17:30 – 18:30
Chair: Rafael Méndez

Germán A. Luna-Acosta

Benemérita Universidad Autónoma de Puebla

Everything you wanted to know about the square well but were afraid to ask

We consider arbitrary localized scattering potentials in one-dimensional semi infinite space. Within the context of the Reaction Matrix Theory we show the relation between the cross section σ, time delay $\tau(k)$, trapping probability $P(k)$, and the "effective dwelling distance" $l(k)$. $l(k) = 2\partial\phi/\partial k$. where ϕ is the resonance part of the phase shift θ. Using natural boundary conditions at the resonances of $l(k)$ we obtain one-level formulas for (k) itself and the other scattering functions. We show analytically that the peaks of $l(k)$ and τ occur in a small neighboorhod of κ_n while the peaks of the resonance part of the cross section σ_ϕ and of $P(k)$ occur in a small neighborhood of $|K_n|$ where $K_n = \kappa_n - i\eta_n$ is the n^{th} resonant pole in wave number complex space. The one-level predictions are in excellent agreement with the exact calculations of the paradigmatic square well potential. Usefulness of our results are discussed in light of the actual necessity of accurately extracting S matrix poles from data in nuclear and particle physics scattering experiments.