Dynamics Days Europe 2018, 3-7 September

Minisymposium "Complex dynamics of quantum systems"

1. **Eckehard Schöll (Berlin)"*Quantum signatures of chimera states*"**

Abstract: Chimera states are complex spatiotemporal patterns in networks of identical oscillators, characterized by the coexistence of synchronized and desynchronized dynamics. Here we propose to extend the phenomenon of chimera states to the quantum regime, and uncover intriguing quantum signatures of these states [1]. We calculate the quantum fluctuations about semiclassical trajectories and demonstrate that chimera states in the quantum regime can be characterized by bosonic squeezing, weighted quantum correlations, and measures of mutual information. Our findings reveal the relation of chimera states to quantum information theory, and give promising directions for experimental realization of chimera states in quantum systems.

[1] V. Bastidas, I. Omelchenko, A. Zakharova, E. Schöll, and T. Brandes: Quantum signatures of chimera states, Phys. Rev. E 92, 062924 (2015).

2. **Alexey Yulin (St. Petersburg) "*Complex dynamics and synchronization of exciton-polariton states in semiconductor microcavities*".**

Abstract: In the first part of the talk the dynamics of spatially separated clouds of polariton condensates is considered. Each of the cloud is excited by positive gain caused by the incoherent excitons. It is known that the interaction between two spatially separated polariton clouds can result into their mutual synchronization and in the formation of coherent polariton molecules. The molecules can be affected by external coherent light with the frequency close to the frequency of the polaritons. The bifurcations leading to the switching between different synchronization regimes are considered in the present work. It is also discussed in the talk how the synchronization can be used to control exciton-polariton condensates. The second part of the talk is devoted to the synchronization of different polarizations of the polariton condensates in the presence of spin-orbit interaction. We show that, depending on the parameters, the polaritons can condense into the states with different total angular momentum. It is argued that the switching between the states can be understood in term of the interplay of the synchronization between the polarizations in each of the clouds and by the synchronization of the neighbouring clouds.

3. **Sergey Saveliev (Loughborough)** ***"Modelling diffusive memristors for neuron emulations and neuromorphic computer applications".***

Abstract: Recently fabricated volatile diffusive memristor [1,2] has demonstrated an ability to emulate neurons. In particular, it exhibits integrate-and-fire neural dynamics, depression effect after applying many voltage pulses, as well as can generate current-spikes if a DC voltage above resistive switching threshold is applied. A combination of diffusive memristors with capacitance and volatile shift memristors allowed to design and implement [3] a neuromorphic device enable unsupervised

machine learning. Moreover, a stochastic resistance switching [2] of diffusive memristors allowed to use them as true random number generators [3]. In this talk, I will discuss modelling of diffusive memristors taking into account diffusion of Ag nanoclusters between memristor terminals for different electric circuits and thermal relaxation in these devices [1-4].

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2. R. Midya, Z. Wang, J. Zhang, S.E. Savel'ev, C. Li, M. Rao, M.H. Jang, S. Joshi, H. Jiang, P. Lin, K. Norris, N. Ge, Q. Wu, M. Barnell, Z. Li, H. L. Xin, R.S. Williams, Q. Xia, J.J. Yang, Anatomy of Ag/Hafnia-Based Selectors with 1010 Nonlinearity, Advanced Materials, 29, 1604457 (2017).

3. H. Jiang, D. Belkin, S. Savel'ev, S. Lin, Z. Wang, Y. Li, S. Joshi, R. Midya, C. Li, M. Rao, M. Barnell, Q. Wu, J.J. Yang, Q. Xia, A novel true random number generator based on a stochastic diffusive memristor, Nature Communications 8, 882 (2017).

4. Z. Wang, S. Joshi, S. Savel'ev, W. Song, R. Midya, Y. Li, M. Rao, P. Yan, S. Asapu, Y. Zhuo, H. Jiang, P. Lin, C. Li, J. H. Yoon, N. K. Upadhyay, J. Zhang, M. Hu, J. P. Strachan, M. Barnell, Q. Wu, H. Wu, R. S. Williams, Q. Xia, J. J. Yang, Fully memristive neural networks for pattern classification with unsupervised learning, Nature Electronics 1, 137–145 (2018).

4. **Vladimir Makarov (Saratov)** ***"Dynamical chaos in arrays of Rydberg atoms"***

Abstract: We study the nonlinear dynamics of the Rydberg atoms chains. The chaotic and hyperchaotic behavior is revealed with increasing number of atoms in the chain. We also investigate route from periodic dynamics to chaotic one and observe the effect of the growth of the number of positive Lyapunov exponents with the increase of chain length. We show the possibility of control and suppression of hyperchaos in the Rydberg atoms chain by means of an external parametric effect.

5. **Kirill Alekseev (Loughborough)** ***"Spatial profiles of electric field in nanostrustuters as a dynamical system"***

We consider spatial distributions of the electric field and the density of mobile charges in a one-dimensional solid sample with charge injection from a complex contact. This textbook-like simplest dynamical system combines the Poisson and continuity equations together with a given dependence of the drift velocity on the electric field, and the boundary condition defined by the injecting contact. The model has many interesting

applications, including useful description of nonuniform field profiles in modern organic electronic devices. Here we apply this model to quantum superlattice devices operating in the miniband transport regime. In this case the model is analytically solvable, and we analyse several physically interesting limits. In particular, we show how to reach the uniform field in conditions of negative differential mobility of electrons. This has important implications for operation of active semiconductor devices able to amplify and generate HF electromagnetic radiation.

6. **Richard Hill (Nottingham)** "***Diamagnetic levitation of spinning and highly charged liquid drops"***

Abstract: In this talk I will review our experimental studies of the shapes and stability of rapidly spinning, electrically charged liquid drops [1-4]. The liquid drop forms the basis of models of physics on an extraordinary range of length scales, from the astronomical scale down to the scale of the atomic nucleus. The successes of the liquid drop model are well-known; its extension to include a centrifugal term has more recently been used to illuminate ongoing studies of high spin heavy nuclei. In our experimental studies of the stability of liquid drops we use a strong, 18 tesla magnetic field produced by a superconducting coil to suspend cm-sized droplets by diamagnetic levitation. Using this technique, the force of gravity is balanced at the molecular level, allowing drops of water and alcohol (and other diamagnetic objects) to be suspended in a weightless environment (FIG. 1).

The equilibrium shape of the drops changes as we spin them up: they deform from spherical to peanut-shaped and eventually break apart. I will discuss recent experiments showing the effect of electric charge on the equilibrium shapes and fission modes of the spinning droplet [1] (FIG.2).

FIG. 1. *Top) Droplets of water levitating in a superconducting magnet at the University of Nottingham. Bottom) From left to right: magnetically-levitated bismuth granules shaken in water; a rapidly spinning levitated water droplet undergoing fission; levitated fruit flies.*

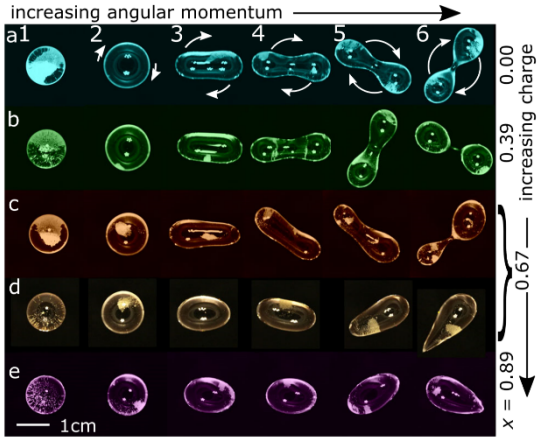

FIG. 2. *The evolution of the equilibrium shapes of charged ethanol drops with increasing angular momentum;* $x \propto (charge)^2$

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[2] K. A. Baldwin, Samuel L. Butler, R.J.A. Hill Sci. Rep., **5**, 7660 (2015).

[3] R. J. A. Hill, L. Eaves, Appl. Phys. Lett., **100**, 114106 (2012).

[4] R. J. A. Hill, L. Eaves, Phys. Rev. Lett., **101**, 234501 (2008).

7. **Feo Kusmartsev (Loughborough)** *"*Stability and Dynamics of Excitons in 2D crystals*"*

Abstract: We describe a new type of dynamical phenomena which may arise in two-dimensional crystals which number is now huge. Having internal sensitivity to the buckling such crystal have therewith a strong intention to the self-trapping of the charge current carriers and excitons. Here we describe a phenomenon, where individual excitons may be self-trapped in a potential well created by buckling they induce. The self-trapped and free excitons may coexist and influence each other. We determine a criterion for such a co-existence and dynamics of these excitons created by various light irradiation of 2D crystals. The self-trapped is characterised by strong local lattice distortions that may generate lattice defects. Therewith making an analysis of these distortions we found that the light-matter interaction in 2D crystals is very important and may influence of the aging of these materials.

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8. **Apostolos Apostolakis (Prague)** ***"Absolute negative conductivity in biased semiconductor superlattices driven by a plane wave."***

Abstract: The control of coherent phonon sources can have an exceptional impact on a wide range of properties of solids and artificial nanostructures. In particular, the amplification of phonons in semiconductor superlattices (SLs) is experimentally feasible by exploiting the intraminiband and nonlinear character of the electron transport [1]. Recently, we analyzed the related nonlinear acoustoelectric effects in SL utilizing semiclassical nonperturbative methods [2]. The calculations revealed that the action of

a strong phonon wave induces drastic changes in the direction and the magnitude of the carrier drift velocity. These transport effects are associated to global bifurcations developing with an increase of the wave amplitude, which serves a control parameter. These global bifurcations dictate specific topological criteria for the transformation of the system phase space. Here we additionally show that a new mechanism of absolute negative conductance (ANC) can be stimulated by the propagating plane wave similar to the one caused by alternating electric fields. In this view the ANC is an extraordinary but reasonable manifestation of the global bifurcations which can be effectively associated with conditions for dynamic localization. Finally, we discuss how the existing dynamic instabilities in an acoustically driven SL can be harvested to provide amplification of THz electromagnetic waves with or without electric bias.

REFERENCES

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[2] A. Apostolakis, M.K. Awodele, K.N. Alekseev, F.V. Kusmartsev, A.G. Balanov; *Phys. Rev. E* **95** (2017) 062203.

9. Xanthippi Zianni (Lamia), "Heat dynamics control in geometry-modulated nanostructures".

Abstract: Heat transfer at the nanoscale is currently a major topic of scientific research because of its importance in many technological applications. It is related with the transport properties of electrons and phonons. Although the transport properties of nanostructures have been extensively studied in the different transport regimes, fundamental knowledge is still needed in order to understand and control heat dynamics in non-uniform nanostructures. Quantum confinement effects dominate the heat transfer at small dimensions and low temperatures. Enhanced scattering limits the phonon thermal conduction in the presence of boundaries, interfaces and in-homogeneities. The heat transmission probability is closely related to the characteristic dimensions of the nanostructure. We have shown that heat dynamics can be controlled by appropriately modulating the geometry of the nanostructure. Multiple dimensions may coexist so that thermal transport is determined by the interplay between ballistic and diffusive effects. We will discuss our theoretical work in this topic and refer to recent experimental findings of other researchers.