DY 37: Nonlinear Dynamics, Synchronization and Chaos

Time: Wednesday 10:00–12:00 Location: H48

DY 37.1 Wed 10:00 H48

Synchronization patterns in hierarchical networks — •Sanjukta Krishnagopal[1,2], Judith Lehnert[1], and Eckehard Schöll[1] — [1]Institut für Theoretische Physik, TU-Berlin, Hardenbergstr 36, 10623 Berlin, Germany, — [2]Birla Institute of Technology and Science - Pilani K. K. Birla Goa Campus, NH 17B Bypass Road, Zuarinagar, Sancoale, 403726 Goa, India.

We consider Stuart-Landau oscillators, a generic model for systems close to a Hopf bifurcation, coupled in a hierarchical (fractal) topology. We present an analytic study of these networks using an extension of the eigensolution concept first introduced in [1]. The resulting eigensolutions of the network are found to be cluster states, where the nodes in the network are synchronized in clusters with a constant phase shift between the clusters. For hierarchical networks in particular, we study the effect of fractal dimension, base pattern and number of iterations on network dynamics.

[1] W. Poel, A. Zakharova, E. Schöll, Phys. Rev. E 91, 022915 (2015)

DY 37.2 Wed 10:15 H48

Injection Locking in the Quantum Regime — •Steffen Holzinger[1], Elisabeth Schlottmann[1], Benjamin Lingnau[2], Kathy Lüdge[2], Christian Schneider[3], Martin Kamp[3], Sven Höfling[3], Janik Wolters[1], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Berlin, Germany — [2]Institut für Theoretische Physik, Technische Universität Berlin, Berlin, Germany — [3]Technische Physik, Julius-Maximilians-Universität Würzburg, Würzburg, Germany

The frequency of an oscillator can be controlled by injecting an external signal. This general concept in non-linear dynamics can be applied to plenty of physical and biological systems. In classical systems this control is well understood by Adler's theory and modifications thereof. In the present work we explore the phenomenon of injection locking, widely applied in standard semiconductor lasers, for the first time in quantum-dot microlasers operating in the regime of cavity quantum electrodynamics (cQED) with on average only few tens of photons in the cavity. In contrast to predictions of classical deterministic rate equations, we find the laser in a superposition of oscillating synchronized to the external signal and at its solitary frequency. With semi-classical rate equations based on a quantum Langevin approach we can show that our experimental results on "partial injection locking" are specific to non-linear cQED systems where cavity enhanced spontaneous emission noise plays an important role. As such, our results pave the way for unravelling exciting effects of injection locking and synchronization in the quantum regime.

DY 37.3 Wed 10:30 H48

Synchronization of particle motion in compressed two-dimensional plasma crystals — •Ingo Laut[1], Christoph Räth[1], Sergey Zhdanov[2], Vladimir Nosenko[1], Lénaïc Couëdel[3], and Hubertus M. Thomas[1] — [1]Deutsches Zentrum für Luft- und Raumfahrt, Forschungsgruppe Komplexe Plasmen, Weßling — [2]Max-Planck-Institut für Extraterrestrische Physik, Garching — [3]CNRS, Aix-Marseille Université, Laboratoire de Physique des Interactions Ioniques et Moléculaires, Marseille, France

Two-dimensional complex plasma crystals are an ideal model system to study dynamic processes on the kinetic level. Recently, synchronized motion of alternating in-phase and anti-phase particle lines was observed during the so-called mode-coupling instability (MCI), where the out-of-plane wave mode of the crystal couples to the longitudinal mode. While MCI is equally strong in three directions for an ideal hexagonal lattice, it was observed in only two directions in the experiment.

Here, we demonstrate with molecular dynamics simulations that an asymmetry in the horizontal confinement of the plasma crystal can cause this anisotropic ignition of MCI. The confinement asymmetry leads to a deformation of the hexagonal lattice that is typically observed in experiments. The instability is accompanied by synchronized particle motion that is characterized by a new order parameter. This order parameter is sensitive to the explicit direction-dependency of the synchronization pattern.

DY 37.4 Wed 10:45 H48

A combined time averaging and frequency mixing approach to parameter identification in nonlinear response — •Si Mohamed Sah, Daniel Forchheimer, Riccardo Borgani, and David B. Haviland — Royal Institute of Technology KTH, Applied Physics SE - 106 91 Stockholm Sweden

We present a method for identifying the parameters of a model describing the tip-sample interaction force in Intermodulation Atomic Force Microscopy (ImAFM). The method uses analytic expressions for the slow-time amplitude and phase evolution, obtained from time-averaging over the rapidly oscillating part of the cantilever dynamics. The slow-time behavior can be easily obtained in the experiment by down-shifting the measured intermodulation spectrum that results when a high-Q resonator is perturbed by nonlinearity. A direct fit of the theoretical expressions to the experimental data gives the best-fit parameters for the model. The method combines and complements previous work [1,2] and it allows for computationally more efficient parameter mapping with ImAFM. Results for both simulation and experiment are shown.

References:
1) Platz, D., Forchhheimer, D., Tholen, E. A. & Haviland, D. B., Interaction imaging with amplitude-dependence force spectroscopy. Nat. Commun. 4, 1360 (2013).
2) Forchheimer, D., Platz, D., Tholen, E. A. & Haviland, D., Model-based extraction of material properties in multifrequency atomic force microscopy. Phys. Rev. B 85, 195449 (2012).

DY 37.5 Wed 11:00 H48

Eigenmode decomposition for synchronized solutions in networks with heterogeneous delay coupling — •Andreas Otto[1], Gabor Orosz[2], Daniel Bachrathy[3], and Günter Radons[1] — [1]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]Department of Mechanical Engineering, University of Michigan, Ann Arbor, MI 48109, USA — [3]Department of Applied Mechanics, Budapest University of Technology and Economics , H1111, Budapest, Hungary

Synchronization in networks of delay-coupled nonlinear systems can be found, for example, in social systems, biology, engineering or physics. In technical applications, e.g. in coupled semiconductor lasers, the time-delays can be tuned to be identical, whereas in real world systems, such as neuronal or social networks, the delays are typically heterogeneous. For networks with instantaneous or identical delays the master stability function can be used to analyze the stability of the network eigenmodes. For heterogeneous delays this approach is restricted to the specific case, where the coupling matrices for the different delays commute. A general approach for the decomposition of the network eigenmodes around synchronized equilibria has been proposed in [1]. In this talk, an extension of this general approach for the eigenmode decomposition around synchronized periodic orbits is presented. In this case the master stability function becomes, in general, a periodic delay differential equation with multiple delays. Numerical results on the stability are shown for delay-coupled Hodgkin-Huxley neurons.

[1] R. Szalai and G. Orosz, *Phys. Rev. E* **88**, 040902 (2013).

DY 37.6 Wed 11:15 H48

Periodic sequence of stabilized wave segments in excitable media — Vladimir Zykov and •Eberhard Bodenschatz — MPI of the Dynamics and Self-Organization, Goettingen, Germany

Wave segments represent an interesting and important example of spatio-temporal pattern formation in a broad class of nonlinear dynamic systems, so-called excitable media. For a given excitability a medium supports propagation of a wave segment with a selected size and shape, which is intrinsically unstable, but can be stabilized by an adequate noninvasive feedback control. For the case of a solitary propagating wave segments a universal selection rules have been found by use a free-boundary approach [1,2]. The main aim of our study is to generalize these results on a case of a periodic sequence of wave segments. To this aim a periodic sequence of stabilized wave segments is numerically studied by use of a generic reaction-diffusion model. In addition, the free-boundary approach is applied which allows us to determine the wave segment shape and the speed as functions of the medium parametersa high accuracy.

[1] A. Kothe, V.S. Zykov and H. Engel, Phys. Rev. Lett., 103, 154102 (2009). [2] V.S. Zykov and E. Bodenschatz, New Journal of Physics, 16, 043030 (2014).

DY 37.7 Wed 11:30 H48

Impact of intermittent power fluctuations on the dynamics of power grids — Katrin Schmietendorf[1], Joachim Peinke[1], and •Oliver Kamps[2] — [1]ForWind - Center for Wind Energy Research, Institute of Physics, University of Oldenburg, Germany — [2]Center for Nonlinear Science, University of Münster

The increasing share of fluctuating energy sources like wind energy poses big challenges for the stability of power grids and the resilience of energy supply systems in general. From the physics point of view the phase and voltage dynamics of a power grid can be described by a Kuramoto-like model of coupled oscillators [1]. To investigate the influence of wind energy production, which is known to exhibit strongly non-Gaussian statistics [2], on the phase and voltage stability we use a Langevin type model mimicking the main features of wind power time series. We compare our findings with results obtained for Gaussian noise and real power time series.

[1] K. Schmietendorf, J. Peinke, O. Kamps, and R. Friedrich, EPJ STI 223, p. 2577-2592, 2014

[2] P. Milan, M. Wächter, and J. Peinke, Phys. Rev. Lett., vol. 110, p. 138701, 2013

DY 37.8 Wed 11:45 H48

Collective Failure due to Multistability in Oscillator Networks and Power Grid — •Debsankha Manik[1], Dirk Witthaut[2], and Marc Timme[1] — [1]Network Dynamics Group, Max Planck Institute for Dynamics anf self-Organization, 37077 Göttingen — [2]Forschungszentrum Jülich, Institute of Energy and Climate Research Systems Analysis and Technology Evaluation (IEK-STE), 52425 Jülich

Networks of phase oscillators model the collective dynamics of various interacting physical and biological systems, ranging from electric power grid operation to neuronal rhythms. Here we show that the number of stable steady states in phase oscillator systems scales with the length of the topological cycles in the network such that for non-global coupling, multistable steady states may emerge. The clustering of similar natural frequencies favour fewer stable states, whereas homogeneous frequency distributions favour more. Intriguingly, multistability prevails even under conditions for which stable states have been claimed to be unique. This multistability may have significant impact on the collective dynamics of such networks: for example, in power grids where the transmission lines have structural limitations on the maximum load they can safely carry, perturbations may induce switching to different steady states, strongly alter the flow patterns, and in turn yield a collective failure of the grid.

Supported by the BMBF under grant no. 03SF0472E.