DY 33: Delay and Feedback Dynamics

Time: Tuesday 14:00–16:00 Location: BH-N 334

DY 33.1 Tue 14:00 BH-N 334

Exploring chaos synchronization in quantum-dot micropillar lasers coupled with delay — •Xavier Porte[1], Sören Kreinberg[1], Steffen Holzinger[1], David Schicke[2], Benjamin Lingnau[2], Martin Kamp[3], Christian Schneider[3], Sven Höfling[3,4], Kathy Lüdge[2], 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 — [4]School of Physics and Astronomy, University of St Andrews, Scotland

Spontaneous synchronization is a universal behavior of coupled systems that only recently is being explored in the quantum domain. A particularly intriguing case is the phenomenon of chaos synchronization between nonlinear oscillators when they are coupled with delay. Semiconductor lasers are excellent examples of such systems, offering the additional key advantage of potential miniaturization to the limits of cavity quantum electrodynamics. In the present work, we explore the phenomenon of chaos synchronization applied to quantum-dot based micropillar lasers. We optically couple two nanolasers in a relay configuration, where both lasers receive self- and mutual-coupling. We investigate the coupling parameters dependencies and their influence on the correlation of the dynamics. Different synchronization regimes are demonstrated like leader-laggard and zero-lag synchronization. Our results pave the way to use nanolasers as testbed systems to study chaos synchronization in the quantum regime.

DY 33.2 Tue 14:15 BH-N 334

Laminar chaos — •Andreas Otto, David Müller, and Günter Radons — Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany

Time delay systems can be found in various fields such as engineering, biology and physics. In the scientific literature many results exist for systems with constant delay. However, in reality the delays are typically not constant but rather time-varying. Recently we found that there are two fundamental classes of time-varying delays [1, 2]. Systems with conservative delay are equivalent to systems with constant delay. On the other hand, there are systems with dissipative delay, which cannot be transformed to systems with constant delay and are associated with fundamentally different dynamic properties.

In this talk we show that nonlinear systems with large dissipative delay can exhibit a new kind of chaotic behavior characterized by laminar phases, which are periodically interrupted by irregular bursts. In particular, the output intensity during the laminar phases remains almost constant, but its level varies chaotically from phase to phase. The periodic dynamics of the lengths and the chaotic dynamics of the intensity levels can be understood and also tuned via two one-dimensional maps, which can be deduced from the nonlinearity of the delay equation and from the delay variation, respectively.

[1] A. Otto, D. Müller and G. Radons, Phys. Rev. Lett. 118, 044104 (2017).

[2] D. Müller, A. Otto and G. Radons, Phys. Rev. E 95, 062214 (2017).

DY 33.3 Tue 14:30 BH-N 334

Small changes, big effect: The dimension of chaotic attractors of dynamical systems with time-varying delay — •David Müller, Andreas Otto, and Günter Radons — Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany

For many systems arising in biology, climate dynamics and engineering the influence of time-delays can not be neglected. Although taking into account environmental fluctuations by introducing time-varying delays can lead to more realistic models, the delay is often considered constant and only a few publications deal with the effect of a time-varying delay on the dynamics of the involved systems.

Recently, we identified two classes of time-varying delays, which are characterized by fundamental differences in the tangent space dynamics of the related systems [1,2]. In this talk, we demonstrate that introducing a time-varying delay also leads to drastic differences in the properties of chaotic attractors of systems with large delay. In detail, the dimension of chaotic attractors of systems with *conservative delay* is typically much larger than the dimension of attractors of systems with *dissipative delay*. Due to the fractal dependence of the delay class on the delay parameters, arbitrary small changes of the delay parameters can cause huge variations of the attractor dimension.

[1] A. Otto, D. Müller and G. Radons, Phys. Rev. Lett. 118, 044104 (2017).

[2] D. Müller, A. Otto and G. Radons, Phys. Rev. E 95, 062214 (2017).

DY 33.4 Tue 14:45 BH-N 334

Dynamics and bifurcation analysis of a passively mode-locked v-shaped semiconductor laser — •Anna-Belle Garten, Lina Jaurigue, and Kathy Lüdge — Institut f. Theo. Physik, Sekr. EW 7-1,Technische Universtität Berlin, Berlin, Germany

Passively mode-locked vertical external-cavity surface-emitting lasers (VECSEL) can produce femtoseconds pulses with high peak powers [1]. These lasers are of interest for driving nonlinear optical processes, e.g. frequency doubling for material processing and multiphoton microscopy. VECSEL mode-locked lasers typically have a v-shaped cavity, i.e. the pulse passes through gain chip twice per roundtrip.

In this contribution we investigate the influence of the geometry on the dynamics. We model the system with a set of coupled delay differential equations which take into account the v-shaped geometry. We solve these equations numerical and analyse the bifurcations of this system. Solutions are found which are not found in an equivalent linear cavity, e.g. double pulse solutions with identical puls heights but asymmetric interspike interval time. These solutions differ from double pulse solutions found in [2]. In [2] the solutions are long lived transients, arising due to the long cavity round trip time compared with the time scales of the carrier dynamics. Whereas in the v-shaped cavity they are stable solutions arising due to the geometry.

[1]C. Alfieri, D. Waldburger, S. Link, E. Gini, M. Golling, G. Eisenstein, and U. Keller, Opt. Express 25, 6402-6420 (2017)

[2] M. Marconi, J. Javaloyes, S. Balle, and M. Giudici, OSA Technical Digest (online) (Optical Society of America, 2014), paper NW3A.8.

DY 33.5 Tue 15:00 BH-N 334

Dynamics of Temporal Localized States in Passively Mode-Locked Semiconductor Lasers — •Svetlana Gurevich[1], Christian Schelte[1,2], and Julien Javaloyes[2] — [1]Institute for Theoretical Physics, University of Münster, Wilhelm-Klemm-Str. 9, 48149 Münster, Germany — [2]Departament de Física, Universitat de les Illes Balears, C/ Valldemossa km 7.5, 07122 Mallorca, Spain

We are interested in the emergence and the stability of temporal localized structures in the output of a semiconductor laser passively mode-locked by a saturable absorber in the long cavity regime. Our analysis is based upon a generic model of mode-locking that consists in a time-delayed dynamical system,but also upon a much more numerically efficient, yet approximate, partial differential equation. We compare the results of the bifurcation analysis of both models in order to assess up to which point the two approaches are equivalent. In particular, by a detailed bifurcation analysis we show that additional solution branches that consist in multi-pulse solutions exist. Further, we demonstrate that the various solution curves for the single and multi-peak pulses can splice and intersect each other via transcritical bifurcations, leading to a complex web of solution. In addition, we disclose the existence of secondary dynamical instabilities where the pulses develop regular and subsequent irregular temporal oscillations.

DY 33.6 Tue 15:15 BH-N 334

Localized Structures in an inhomogeneous Lugiato-Lefever equation with time-delayed feedback — •Felix Tabbert[1], Mustapha Tlidi[2], Krassimir Panajotov[3,4], and Svetlana Gurevich[1] — [1]Institute for Theoretical Physics, University of Münster, Wilhelm-Klemm-Str. 9, D-48149 Münster — [2]Faculté des Sciences, Université Libre de Bruxelles (ULB), Code Postal 231, Campus Plaine, Bruxelles B-1050, Belgium — [3]Vrije Universiteit Brussel, Department of Applied Physics & Photonics, Pleinlaan 2, B-1050 Brussels, Belgium. — [4]Institute of Solid State Physics, 72 Tzarigradsko Chaussee Blvd., 1784 Sofia, Bulgaria

We discuss the destabilization mechanisms of localized structures in an inhomogeneous nonlinear cavity subjected to injection and to time-delayed feedback. This simple setup is described by the delayed Lugiato-Lefever equation. We analyze the pinning behavior of spatial inhomogeneities on localized structures by introducing a potential induced by an inhomogeneous injection beam. Further, we identify conditions under which these structures are destabilized and describe different bifurcation scenarios. We show that in the presence of the inhomogeneity, delayed feedback induces an Andronov-Hopf-bifurcation that leads to oscillations of the localized structure around the inhomogeneity. Finally we show that for large values of the feedback strength, the localized structure escapes from the potential well and starts to drift and discuss different scenarios, where inhomogeneities are introduced, e.g. in the detuning parameter.

DY 33.7 Tue 15:30 BH-N 334

Feedback enhanced quantum beating due to resonant dipole-dipole coupling — •Manuel Kraft[1], Tymoteusz Tula[2], Kisa Barkemeyer[1], Anja Metelmann[3], Andreas Knorr[1], and Alexander Carmele[1] — [1]TU Berlin, Institute of Theoretical Physics — [2]Wroclaw University of Science and Technology, Faculty of Fundamental Problems of Technology — [3]Princeton University, Department of Electrical Engineering

We investigate the propagation of few-photon Fock-states in a one-dimensional waveguide scattered by two dipole-dipole coupled atoms. Using a scattering method based on the Lippmann-Schwinger equation [1], we study photon-photon correlations of the photons in the reflected and transmitted field. Depending on the dipole-dipole interaction strength, we observe highly damped oscillations in the second-order correlation function. To increase the visibility, we introduce quantum coherent time-delayed feedback [2] by terminating one end of the waveguide by a resonator, acting as a mirror. Our results clearly show that the dipole-dipole induced quantum beats can be intensified and stabilized where the long-time beating frequency is sensitive to the dipole-dipole interaction strength. Since the interaction strength depends strongly on the separation of the emitters, our method may provide a way to probe interatomic coupling and distances on a deep subwavelength scale.

[1] Zheng *et al.*, Phys. Rev. Lett. **110**, 113601 (2013)
[2] Carmele, *et al.* Phys. Rev. Lett. **110**, 013601 (2013)

DY 33.8 Tue 15:45 BH-N 334

Dynamics of Quantum-Dot Based Micropillar Lasers with Optoelectronic Feedback — •Andrej Krimlowski — Institut für Theoretische Physik, Technische Universität Berlin

Semiconductor lasers with self-coupled delayed feedback show an extensive variety of physical phenomenons including nonlinear dynamics such as stabilized laser self-pulsing and chaos. We numerically investigate an on-chip optoelectronic feedback setup in a micropillar laser-detector assembly [1]. In this setup, the optical output signal of a micropillar laser is fed back into the laser pump current with an electronic delay. The system is characterized by strong spontaneous emission as well as a temperature dependent gain. The dependence of the system's dynamics on the temperature induces a time scale separation leading to complex dynamics. We perform a linear stability analysis and a numerical bifurcation analysis in dependence on system parameters as the feedback strength, the pump current and the maximum feedback current. We find a multitude of qualitatively different dynamics including complex states with periodic and non-periodic solutions and strong multistability of the system.