DY 51: Delay and feedback Dynamics

Time: Thursday 10:00–11:15 Location: H47

DY 51.1 Thu 10:00 H47

Dynamical systems with time-varying delay: Dissipative and more dissipative systems — •David Müller, Andreas Otto, and Günter Radons — Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany

Dynamical systems with time-varying delay arise in many fields such as biology, chemistry, economy, engineering and physics.

We identify two different classes of systems with time-varying delay, whereby the the classification depends only on the characteristics of the delay. Systems with *conservative* delay can be transformed to systems with constant delay. Consequently, they exhibit the same type of dynamics. Systems with *dissipative* delay can not be transformed to systems with constant delay and the related dynamics differs from the dynamics of systems with constant delay. In typical models the delay is given by a parameter family. The systems show both types of delays and in general the delay type depends in a fractal manner on the delay parameters.

The difference in the dynamics of the delay classes becomes clear by the analysis of the evolution of small volumes on finite-dimensional subspaces of the infinite-dimensional state space of the delay system. For constant and conservative delays the system is dissipative. Hence, conservative time-varying delays "conserve" the well-known scaling behavior of the mean relaxation rate of the volume evolution corresponding to constant delays, which leads to the known logarithmic scaling of the Lyapunov spectrum. Dissipative delays lead to an additional contribution to the relaxation rate and change the scaling behavior.

DY 51.2 Thu 10:15 H47

Quantum coherent time-delayed feedback control of squeezing — •Manuel Kraft[1], Sven M. Hein[1], Judith Lehnert[2], Eckehard Schöll[2], Stephen Hughes[3], Alexander Carmele[1], and Andreas Knorr[1] — [1]Technische Universität Berlin, Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Technische Universität Berlin, Institut für Theoretische Physik, Nichtlineare Dynamik und Kontrolle, Hardenbergstr. 36, 10623 Berlin, Germany — [3]Department of Physics, Engineering Physics and Astronomy, Queen's University, Kingston, Ontario, Canada, K7L 3N6

Quantum coherent control schemes are measurement-free methods to control open quantum systems. In contrast to measurement-based schemes the control signals are fully quantum coherent and therefore do not introduce measurement induced noise into the system. We concentrate on the specific situation of a Pyragas-type control scheme where instantaneous and time-delayed signals are fed back directly into the quantum dynamics of the observable. In this talk we present how time-delayed quantum coherent self-feedback control [1, 2] can enhance the squeezing in the output fields of an externally pumped cavity containing a second order nonlinear crystal. This is of particular importance for phase and amplitude noise reduction.

[1] Carmele *et al.* Phys. Rev. Lett. **110**, 013601 (2013)
[2] Schulze *et al.* Phys. Rev. A **89**, 041801 (2014)

DY 51.3 Thu 10:30 H47

Harmonic Oscillator & PID: Precise and Fast Control of Microfluidic Transport — •Claus Fütterer — Biophysical Tools GmbH/Forschung, 04317 Leipzig, Germany

Microfluidic flow control presents a challenge as most methods rely on volume displacement (syringe pump, peristaltic pump). However, the application of pneumatic flow control simplified significantly the task and presents today the state-of-the-art (Fütterer et al., Injection and Flow Control in Microchannels, Lab Chip 4, 351, 2004).

By symmetrisation we could strongly improve the state-of-the-art. We describe the improvements, outline the mathematical model and present measurements. The new approach allows us to apply linear response theory to our control method, which permits total optimization only limited by causality and technical conditions as finite temperature, dead volume and medium properties. It turned out that the equations can be related to the inhomogeneous harmonic oscillator which alleviates the interpretation of the parameters and helps to understand the dynamics significantly. Stability and noise of the stationary as well as the simplest time dependent solutions are further topics of interest.

The presented model can be generalized to numerous other out-of-equilibrium systems involving control of transport of quantities obeying conservation laws.

DY 51.4 Thu 10:45 H47

The Hill-Floquet method for the analysis of periodic solutions in time-delay systems — •Andreas Otto and Günter Radons — Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany

The Hill-Floquet method for the calculation of Floquet multipliers for periodic systems is introduced. The stability of an equilibrium can be analyzed via the characteristic equation. According to Floquet theory, the perturbations around a periodic solution can be decomposed into a periodic and an exponential part. The Fourier expansion of the periodic terms leads to an infinite dimensional characteristic equation, which is known as central equation in solid state physics, multi-frequency approach in engineering or Hill's infinite determinant method.

Based on this method a general transformation from the original finite dimensional periodic system to an infinite dimensional time-invariant system is presented, the so-called Hill-Floquet transformation. The transformation can be also used for the transformation of delay differential equations (DDEs) with periodic coefficients to time-invariant DDEs. As a result, a large variety of established methods for autonomous DDEs are made available for the analysis of periodic DDEs. In this talk, the Hill-Floquet method is combined with a Chebyshev collocation method for the numerical stability analysis of periodic solutions of nonlinear DDEs.

DY 51.5 Thu 11:00 H47

Semi-Analytic Treatment of Phase Noise in Oscillatory Systems under Time-Delayed Feedback Control — •Lina Jaurigue, Benjamin Lingnau, and Kathy Lüdge — Institut f. Theo. Physik, Sekr. EW 7-1, Technische Universität Berlin, Hardenbergstr. 36, 10623Berlin, Germany

We study the effect of delayed coherent optical feedback on the phase noise in oscillatory systems. We derive a semi-analytical method [1] which gives further physical insight into the feedback dependence of the phase noise, and due to greatly reduced computation times allows for the investigation over greater parameter domains. We apply the method to passively-mode-locked semiconductor lasers to calculate the optical pulse timing jitter, showing an excellent agreement with numerical simulations as well as with experimental results. We derive an analytic expression for the timing jitter, which predicts a monotonic decrease in the timing jitter for resonant feedback of increasing delay lengths, scaling approximately as $1/\tau$ with increasing feedback delay time τ. This trend is not related to an increased stability of the system but to the increase in the history of the solutions, which results in the influence of the noise being reduced and the pulse positions being correlated over longer times.

[1] L. Jaurigue, A. Pimenov, D. Rachinskii, E. Schöll, K. Lüdge, and A. Vladimirov, Phys. Rev. A **92**, 053807 (2015)