DY 24: Pattern Formation / Reaction-Diffusion I

Time: Tuesday 14:30–15:45 Location: ZEU 147

DY 24.1 Tue 14:30 ZEU 147

Control of traveling localized spots — •Steffen Martens[1], Christopher Ryll[2], Jakob Löber[1], Fredi Tröltzsch[2], and Harald Engel[1] — [1]Technische Universität Berlin, Institut für Theoretische Physik, 10623 Berlin, Deutschland — [2]Technische Universität Berlin, Institut für Mathematik, 10623 Berlin, Deutschland

Besides traveling waves, moving localized spots represent yet another important class of self-organized spatio-temporal structures in nonequilibrium dissipative systems. In this talk, we present two different approaches to guide localized spots along a pre-given trajectory. First, an analytical solution for the control – being an open-loop control – is proposed which attempts to shift the spot's "center of mass" according to a given protocol of movement without disturbing its profile [J. Löber and H. Engel, PRL **112**, 148305; J. Löber, PRE **89**, 62904]. The control signal is expressed in terms of the uncontrolled spot profile and its propagation velocity; rendering detailed informations about the reaction kinetics unnecessary. Secondly, optimal control with Tikhonov regularization is used. Noteworthy, both control schemes coincide for vanishing regularization term. In particular, our analytic control is an excellent initial guess for the numerical solution of optimal control problems; thereby achieving a substantial computational speedup [C. Ryll et al., *Control of Self-Organizing Nonlinear Systems* (Springer, Berlin-Heidelberg, 2016)].

DY 24.2 Tue 14:45 ZEU 147

Periodic sequence of stabilized wave segments in excitable media — •Vladimir Zykov and Eberhard Bodenschatz — Max-Planck-Institute for Dynamics and Self-Organization, 37077 Göttingen, 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. They have been observed, for instance, in cardiac and cortex tissue, catalytic surface reactions, concentration waves in thin layers of the Belousov-Zhabotinsky reaction or during cell aggregation of Dictyostelium discoideum. For a given excitability a medium supports propagation of a wave segment with a selected size and shape, which is intrinsically unstable. In order to make this solution observable it has to 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. The main aim of our study is to generalize these results on a case of a periodic sequence of wave segments. To this aim the translational motion of a stabilized wave segment in an excitable medium is numerically studied by use of a generic reaction-diffusion model with nonlinear activator-inhibitor kinetic. In addition, the free-boundary approach is applied to determine the wave segment shape and the speed as functions of the medium parameters. We hope that the results obtained in this study are also applicable to the spiral wave dynamics.

DY 24.3 Tue 15:00 ZEU 147

Propagation and Boundary Mediated Control of Reaction-Diffusion Waves in Modulated Tubes — •Alexander Ziepke, Steffen Martens, and Harald Engel — Institut für Theoretische Physik, Technische Universität Berlin, Germany

Propagation of traveling front and pulse solutions to reaction-diffusion equations within periodically modulated tubes is investigated. In the fashion of our recent paper [1], we apply asymptotic analysis for a small changing rate of the tube's cross-section to reduce the dimensionality of the problem. Within this approach, the no-flux condition at the tube's boundary translates into a boundary-induced advection term. Treating the latter as a weak perturbation, we derive an equation of motion for the wave position [2]. Numerical simulations demonstrate that our analytical results predict properly the nonlinear dependence of the propagation velocity on the ratio of the period of the cross-section's spatial modulation to the intrinsic width of the wave solution. As a main feature, we observe finite intervals of propagation failure of waves induced by the tube's modulation. Further, using the derived equation of motion, the inverse problem of calculating the cross-section profile for a given protocol of motion is treated. This allows a geometry based control of chemical wave propagation. Additionally, we discuss the effects of a single bottleneck on periodic pulse trains.

[1] A. Ziepke, S. Martens, and H. Engel, *J. Chem. Phys.*, **145**, 094108 (2016).
[2] J. Löber and H. Engel, *Phys. Rev. Lett.*, **112**, 148305 (2014).

DY 24.4 Tue 15:15 ZEU 147

Hydrodynamic instabilities driven by complex chemical reactions — •Dario M. Escala[1], Jorge Carballido-Landeira[1], Anne DeWit[2], and Alberto P. Munuzuri[1] — [1]Nonlinear Physics Group, Univ. of Santiago de Compostela, Spain — [2]Nonlinear Physical Chemistry Unit, Univ. Libre de 6 Bruxelles (ULB), Belgium

Classical hydrodynamic instabilities in Hele-Shaw cells (like those produced by buoyancy or differences in viscosity) have been extensively studied during decades. The potential applications have aroused major interest in a variety of research fields with the aim of understanding the physics behind it and thus, find ways to control and model these systems. During the past years, researchers have increased the complexity of these investigations proposing interesting couplings between hydrodynamic instabilities and chemical systems. From simple neutralization reactions to more complicated autocatalytic reactions, a broad horizon has been opened where these coupled systems were also extensively analyzed and modeled seeking the description of new instabilities. Here, two setups will be analyzed that clearly demonstrate the constructive role played by the coupling of chemical and hydrodynamic instabilities. First, buoyancy-driven instability is generated due to the oscillatory Belousov-Zhabotinsky reaction. Second, a pH-shifting reaction which produces a new type of viscous finger instability. In both cases, the control parameters are varied. We use advanced optics techniques and numerical simulations as a complementary source of information in order to unveil the mechanisms underlying behind the observed phenomena.

DY 24.5 Tue 15:30 ZEU 147

Transition to chaos: From small to large systems in the Nikolaevskiy model — •Steffen Finger and Stefan Jakob Linz — Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster

The Nikolaevskiy equation originally introduced as a model for seismic waves [1] also appears in many different contexts ranging from instabilities of fronts over electroconvection to reaction-diffusion-systems and serves as a paradigmatic minimal model for the appearance of soft-mode turbulence in most parameter ranges. Extending the work by Tanaka [2] and using numerical simulations and Lyapunov exponent methods, we detect and classify the highly elaborate scenario of different transitions from regular dynamics to spatiotemporal chaos that appears when the system size is varied and periodic boundary conditions are applied.

[1] V. N. Nikolaevskii, Lecture Notes in Engineering 39, 210 (1989).
[2] D. Tanaka, J. Phys. Soc. Jpn. 74, 2223 (2005).