DY 35: Reaction-Diffusion Systems

Time: Thursday 15:00–17:30 Location: HÜL 186

DY 35.1 Thu 15:00 HÜL 186

Position and shape control of traveling waves in reaction-diffusion systems — Jakob Löber, •Steffen Martens, and Harald Engel — Technische Universität, Berlin, Deutschland

We present an efficient and easily applicable method to control the position respectively the shape of traveling wave solutions in reaction-diffusion systems according to a desired protocol of movement. Given this protocol, the control function is found as the solution of a perturbatively derived integral equation. In particular, we derived an analytical expression for the space ($\mathbf{r}$) and time (t) dependent control function $f(\mathbf{r}, t)$ that is valid for a large variety of reaction-diffusion systems and many kinds of protocols, e.g., accelerating, decelerating or periodic protocols. Intriguingly, our control method is expressed in terms of the uncontrolled wave profile and its propagation velocity, rendering detailed informations about the reaction kinetics unnecessary. Noteworthy, this method is very close to optimal controls. An extension of the control method allows to control the shape of traveling fronts as well as localized spots in two and three spatial dimensions.

DY 35.2 Thu 15:15 HÜL 186

A continuous transition between two limits of spiral wave dynamics in an excitable medium — •Vladimir Zykov and Eberhard Bodenschatz — Max Planck Institute for Dynamics and Self-Organization, D-37077 Goettingen, Germany

By application of a free-boundary approach we prove the existence of a continuous transition and a full spectrum of solutions between the two known limits of spiral wave dynamics corresponding to trigger-trigger and trigger-phase waves. We identify a control parameter whose essential importance was not realized in earlier studies of spatio-temporal pattern selection in excitable media. The predictions of the free-boundary approach are in good quantitative agreement with results from numerical reaction-diffusion simulations performed on the modified Barkley model.

DY 35.3 Thu 15:30 HÜL 186

Reaction diffusion patterns: Effects of modulations on traveling waves — •Fabian Bergmann, Marius Jakoby, Lisa Rapp, and Walter Zimmermann — Theoretische Physik, 95440 Universität Bayreuth, Germany

In reaction-diffusion models for chemical reactions [1] and biological systems [2] one often finds bifurcations to traveling waves. If such systems in two dimensions are either restricted to narrow stripes [2] or spatially periodic modulated, waves traveling along a preferred direction are found. Results are presented about the dependence of the travel direction of waves on characteristic reaction and diffusion parameters as well as modulation parameters, including the pulling speed of the modulation. In addition a generic description is presented which is valid near the onset of traveling waves. This generic model covers the behavior of modulated traveling waves found in the reaction diffusion systems.

[1] M. Dolnik, A. R. Rovinsky, A. M. Zhabotinsky, I. R. Epstein, Standing Waves in a Two-Dimensional Reaction-Diffusion Model with the Short-Wave Instability, J. Phys. Chem. A 103, 38 (1999)

[2] J. Schweizer, M. Loose, M. Bonny, K. Kruse, I. Mönch, P. Schwille, Geometry sensing by self-organized protein patterns, PNAS 109, 15382 (2012)

DY 35.4 Thu 15:45 HÜL 186

Turing instability in a scalar reaction-diffusion system with delay — •Andreas Otto, Jian Wang, and Günter Radons — Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany

The existence of diffusion-driven instabilities in scalar systems with time-delay is studied. The so-called Turing instability occurs if the homogeneous steady state of a system is stable in the absence of diffusion but unstable when diffusion is present. As a result spatially inhomogeneous states emerge, which are a subject of current research in physics, biology and chemistry.

To the authors knowledge until now the occurrence of a Turing instability is only known to exist for multi-component systems. In scalar reaction-diffusion systems without or with only one constant delay a Turing instability is not possible. However, diffusion-driven instabilities exist in one component reaction diffusion systems with distributed and/or time-varying delay, which is the topic of this talk.

DY 35.5 Thu 16:00 HÜL 186

Pattern Formation in BZ-AOT Microemulsions Manipulated by Electric Fields — •Patricia Dähmlow and Stefan C. Müller — Otto-von-Guericke University Magdeburg, Germany

Pattern formation in excitable media presents an important phenomenon in biological morphogenesis, electrophysiology and neuronal systems. A rich variety of these patterns can be found in the Belousov-Zhabotinsky (BZ) reaction dissolved in the aerosol OT (AOT) water-in-oil microemulsion (ME).

Using the ferroin- and the bathoferroin-catalyzed BZ reaction, we observed different patterns like Turing patterns, dash waves and discontinuously propagating waves (jumping and bubble waves). By applying an electrical field across the spatially extended solution layer, a linear drift of these patterns can be observed. Also the layer thickness of the ME plays an important role in the development of the patterns, since a thick layer (220 μm) leads to a "smearing out" of the patterns whereas in a thin layer (100 μm) the drift can be clearly recognized.

The application of an electric field to the microemulsion reveals changes in a number of physical properties of the medium. We follow the assumption that this system can act as a model system for long range interactions beyond local coupling by diffusion processes, thus presenting a concept which could be applicable to long range interactions between neurons.

15 min break

DY 35.6 Thu 16:30 HÜL 186

Influence of polymers on silica gel structure and patterns of Belousov-Zhabotinsky reaction — •Claudia Lenk and J. Michael Köhler — Institut für Chemie und Biotechnik, TU Ilmenau, Germany

Spatio-temporal patterns formed in oscillatory chemical, biological or medical systems resemble the state of the system and their analysis reveals thus information about the underlying processes. Thereby the structure of the media plays an important role for the resulting patterns. To investigate the influence of the structure, we perform experiments of the well-known Belousov-Zhabotinsky (BZ) reaction in a silica gel, where the catalyst Ferroin is immobilized in predefined patterns. To enhance the immobilization different polymers are added to the gel matrix. The influence of the polymers on the gel structure is analyzed by scanning electron microscope and Raman measurements. The best immobilization of Ferroin is observed for gels with polyethylene glycol or poly(styrenesulfonic acid-co-maleic acid) sodium salt. Since, e.g., polyethylene glycol can yield standing wave patterns [1], changes of the oscillatory parameters, like frequency and conduction velocity of the BZ waves, are studied. The relation of these changes to the diffusion properties of the BZ reagents and the chemical and electrical properties of the polymer will be discussed.

[1] D. Cuinas *et al.*, J. Chem. Phys. **128**, 244907 (2008).

DY 35.7 Thu 16:45 HÜL 186

Formation of patchy particles by diffusion limited growth — •Timo Bihr[1,2], Huixin Bao[3], Robin Klupp Taylor[3], Udo Seifert[2], and Ana-Sunčana Smith[1] — [1]Institut für Theoretische Physik and Excellence Cluster: Engineering of Advanced Materials, Universität Erlangen-Nürnberg — [2]II. Institut für Theoretische Physik, Universität Stuttgart — [3]Institute of Particle Technology, Universität Erlangen-Nürnberg

Patchy particles can be formed by coating polystyrene particles with ascorbic acid as a precursor for gold. The latter precipitates from the solution onto the particle, diffuses on its surface and attaches to a growing gold patch. We investigate the formation of the patch by Monte Carlo simulations and study the effects of gold concentration, binding and unbinding rates, and the diffusion constant. We obtain a variety of dendrite structures which we characterize by their fractal dimension and the power-law characterizing the growth process. The exponents typical for the diffusion limited aggregation are recovered only in the limit of infinite dilution, whereas reaction limited dynamics is obtained at larger densities, depending on the binding affinity.

Comparison of modeling with experiments shows that decreasing the concentration of the ascorbic acid results in the decrease of binding affinity, whereas increasing the temperature increases the diffusivity. Consequently in both cases, roughening of the dendrite structure of the patches takes place. The understanding of this process allows us to tune the morphology of the patch on the particle from dense cup-like structures to pure dendrites (H. Bao et al. *Nanoscale*, 2014, DOI: 10.1039/C3NR04016J).

DY 35.8 Thu 17:00 HÜL 186

Studying Protein Assembly with Brownian Dynamics of Patchy Particles: from Microscopic to Macroscopic Rates — •Heinrich Klein[1] and Ulrich S. Schwarz[1,2] — [1]Institute for Theoretical Physics, Heidelberg University, Germany — [2]BioQuant, Heidelberg University, Germany

Assembly of protein complexes is of high relevance for the functionality of many biological systems like virus shells, the nuclear pore complex or the actin cytoskeleton. Moreover, recent advances in the fabrication of colloidal particles with anisotropic reactivity (*patchy particles*) provide new opportunities to design self-assembling structures. Here we present a novel computational approach for the Brownian dynamics of patchy particles with fully reversible reactions satisfying detailed balance. Different particles stochastically associate and dissociate with microscopic reaction rates depending on their relative spatial positions. We show how macroscopic rates can be inferred from the microscopic rates and the diffusive properties of the assembly intermediates. As an instructive example, we study the assembly of a pentameric ring structure, for which we find excellent agreement between microscopic results and a macroscopic kinetic description without any adjustable parameters. In summary, we have developed a computational framework which accounts for both the diffusional and the reaction processes underlying protein assembly.

DY 35.9 Thu 17:15 HÜL 186

Photoelectrodissolution of n-type silicon: An oscillatory medium with unusual pattern formation — •Konrad Schönleber, Andreas Heinrich, Elmar Miterreiter, Martin Wiegand, Carla Zensen, and Katharina Krischer — Technische Universität München

We investigate the spatial thickness distribution of oxide layers formed at illuminated n-type silicon samples during the anodic electrodissolution in fluoride containing electrolytes by means of spatially resolved ellipsometric imaging. Spontaneous pattern formation in the oxide thickness can be observed for appropriate parameter values while the total current and spatially averaged oxide thickness oscillate simply periodic. The observed patterns typically consist of several regions on the electrode each showing distinct dynamical behavior giving rise to a rich variety of different states, as e.g. so-called 'Chimera states' and other unusual cluster states. In addition, a novel type of spatial organization involving periodically growing and collapsing oscillating domains with peculiar front dynamics are discussed.