BP 10: Biofluiddynamics

Time: Tuesday 14:00–16:30 Location: HÜL 186

Invited Talk BP 10.1 Tue 14:00 HÜL 186

Biohydrodynamics of biomimetic and bacterial flagella — •Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, D-10623 Berlin, Germany

At the micron scale fluid flow is in the low Reynolds number regime and nature had to be inventive to enable microorganisms to propel themselves in such an environment. Sperm cells, for example, use beating elastic filaments called flagella.

I shortly review our work on modeling a biomimetic flagellum consisting of superparamagnetic beads linked by DNA strands. Attached to a red-blood cell, the first artifical micro swimmer was created actuated by an oscillating magnetic field. The filament can also be attached to a surface in order to explore fluid transport for different beating patterns.

Many types of bacteria propel themselves with the help of a bundle of rotating helical flagella. These flagella can assume different types of helical conformations (polymorphism) depending on temperature, pH value of the solvent and applied external forces or torques as revealed by the tumbling motion of a bacterium. I will talk about our approach to model the flagellar polymorphism on the microscopic level of the flagellin proteins. Then, on a coarse-grained level I will discuss the hydrodynamics of a helical flagellum addressing explicitely the transition between two flagellar polymorphs observed when pulling at the flagellum. The analysis is performed on the basis of a generalized elasticity theory for a helical rod with two helical states. The influence of thermal noise and pulling speed on the force-extension curve is discussed.

BP 10.2 Tue 14:30 HÜL 186

Thermal Nanoparticle Traps: Theory and Experiment — Franz M. Weinert, Philipp Baaske, and •Dieter Braun — Systems Biophysics, Ludwig Maximilians University, Munich, Germany

In the past, we discussed theoretically that thermal gradients in porous rock can accumulate even single nucleic bases more than millionfold in centimeter-sized pore systems [1]. The accumulation is solely driven by a static vertical temperature gradient by convection and thermodiffusion.

We scaled down above mechanism by a factor of 1000. This is possible with light driven microflow [2][3] where the nonlinear combination of thermal expansion with temperature-dependent viscosity drives fluids remotely with a laser scanning microscope. As result we efficiently trap polystyrene beads with diameter of 40nm on the time scale of seconds.

In the future we envisage to combine the trap with the polymerase chain reaction. We previously showed that thermal convection can exponentially replicate DNA by PCR. With above approach we should be able to trap and replicate DNA in the same chamber, opening new possibilities for fast continuous in vitro evolution.

Publications:
[1] PNAS 104, 9346-9351 (2007)
[2] Physical Review Letters 100, 164501 (2008)
[3] Weinert & Braun, Journal of Applied Physics, in press.

BP 10.3 Tue 14:45 HÜL 186

Defined Spatial and Time Resolved Microfluidics for Stimulation of Chemotactic Cells — •Börn Meier, Delphine Arcizet, Joachim Rädler, and Doris Heinrich — Biophysics of Cell Dynamics Group, Fakultät für Physik und Center for Nanoscience (CeNS), Ludwig-Maximilian-Universität München, Geschwister-Scholl-Platz 1, D-80539 München, Germany

The ability of cells to move into the direction of a chemical gradient is an important mechanism involved in physiological responses, like the movement of neutrophils in tissue or for angiogenesis, the development of new blood vessels. In the model organism Dictyostelium discoideum (Dd) it has been shown that the response to chemotactic stimulation occurs within seconds. Therefore it is important to manipulate the chemoattractant concentration on very short timescales, which is possible with the recent developments in microfluidics.

We have built a microfluidic setup to measure the sub-second chemotactic response of single cells, which allows us to expose the cells to defined gradients of chemoattractant, changing directions with switching times down to a few seconds. Consequently we observed a time-dependent directed motion for Dd cells. To study the local protein response to a fast switching gradient by fluorescence imaging, we use knock-out and fluorescently labelled mutants of Dd cells.

We aim at trapping cells by adjusting the switching times of the chemoattractant gradient in a way that the cells repolarise without an actual displacement. Therefore we will be able to perform high precision measurements on immobilised cells.

BP 10.4 Tue 15:00 HÜL 186

Cell surface protein dynamics in microflow — •Eric Stellamanns[1], Sravanti Uppaluri[1], Niko Heddergott[2], Markus Engstler[2], and Thomas Pfohl[1] — [1]Max Planck Institute for Dynamics and Self Organization, Göttingen, Germany — [2]Technical University of Darmstadt, Cellular Dynamics Unit, Darmstadt, Germany

The human bloodstream parasite Trypanosoma brucei has evolved a clever trick to escape its host's immune response. Living in an environment of constant flux, it propels itself with a relative velocity of 20μm/s, washing off any hostile antibody that binds to its variable surface glycoprotein (VSG) coat. Optical tweezers and microfluidic techniques are used to label single VSG dimers of living trypanosomes with quantum dots (Qdots) as antibody mimics. The highly fluorescent Qdots allow us to trace single VSG-Qdot complexes along the cell membrane, thereby we study the effects of flow velocity, fluid viscosity and cell motility on the transport of these "molecular sails". Further we examine hydrodynamic forces on the molecular scale and describe their protein organizing effects in cell membranes.

BP 10.5 Tue 15:15 HÜL 186

Motility Patterns and Structure Formation Dynamics of Physarum Polycephalum — •Christina Oettmeier, Siddharth Deshpande, and Hans-Günther Döbereiner — Institut für Biophysik, Universität Bremen

The plasmodium of the slime mold Physarum Polycephalum is a unicellular organism with a large number of nuclei, which can grow several square centimeters in area. The plasmodium develops veins, which cause reversible shuttle streaming of the endoplasm via periodic contractions. We report on the dynamics of this network during formation, growths, and plasmodium extension as a function of environmental conditions. Especially, we are interested in the role of endoplasmic streaming in network formation.

BP 10.6 Tue 15:30 HÜL 186

Steering chiral swimmers along noisy helical paths — •Benjamin M. Friedrich and Frank Julicher — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden

Helical swimming of microorganisms is ubiquitous in nature and has been observed e.g. for sperm cells, eukaryotic flagellates, and even bacteria. A simple feedback mechanism enables these chiral swimmers to navigate upwards a concentration gradient of a chemoattractant [1]. We characterize the robustness of this chemotaxis strategy in the presence of non-equilibrium fluctuations [2] and derive a formal analogy to the orientation of a dipol in an external field. For an exemplary search problem, we show that search success is maximal for a finite noise level [3]. Different biological swimmers employ various navigational strategies of which chemotaxis along noisy helical paths is just one example. We discuss the availableness of different strategies to a swimmer as a function of the noise level and give biological examples.

[1] B.M.F., F.J.: Proc. Natl. Acad. Sci. USA **104** (2007).
[2] B.M.F., F.J.: New J. Phys., in press.
[3] B.M.F.: Phys. Biol. **5** (2008).

BP 10.7 Tue 15:45 HÜL 186

Theoretical modelling of bacterial motor dynamics — •Eva Baresel and Rudolf Friedrich — Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster

As a model for bacterial motors we consider the dynamics of an ensemble of swimming objects which are composed of two rigidly connected point vortices. The single objects are able to propel or to tumble depending on the circulations of the single point vortices. We discuss the collective behaviour for several of these objects by means of numerical calculations.

BP 10.8 Tue 16:00 HÜL 186

Investigating cross-linking properties of actin structures with holographic optical tweezers in microfluidic systems — •Kai Uhrig[1,2], Rainer Kurre[1,2], Martin Streichfuss[1,2], Friedrich Erbs[1,2], Simon Schulz[1,2], Anabel Clemen[1,2], Tamas Haraszti[1,2], Christian Böhm[1,2], and Joachim Spatz[1,2] — [1]MPI for Metals Research, Dept. Spatz, Heisenbergstr. 3, 70569 Stuttgart — [2]Univ. of Heidelberg, Biophys. Chem. Dept., INF 253, 69120 Heidelberg

The actin cortex is an adaptive chemo-mechanical polymer network located underneath the cell membrane. A multitude of factors and proteins that induce cross-linking, gelification or bundling of filaments controls its shape and mechanical properties. Recent studies on actin network mechanics were always restricted to three dimensional bulk gels, which are believed to show significantly different mechanic behaviour. We used the combination of holographic optical tweezers (HOT) with microfluidic techniques to create two dimensional network structures on trapped microbeads that could be cross-linked and probed subsequently. High-speed imaging was used to monitor force generation due to contraction of the network at all trapped beads simultaneously whilst fluorescence imaging was implemented to follow structural changes of the actin network. In another approach, HOTs and the combination of optical tweezers with PDMS micropillar substrates are used to investigate cross-linking processes in zipper-like structures between freely suspended actin filaments in detail. Force curves for zipping processes as well as for force induced unzipping could be deduced and correlated to fluorescence micrographs of the zipper structures.

BP 10.9 Tue 16:15 HÜL 186

Hydrodynamic description of cortical dynamics in the *C. elegans* zygote — •Justin Bois[1,2], Martin Depken[1,2], Mirjam Mayer[2], Frank Jülicher[1], and Stephan Grill[1,2] — [1]Max Planck Institute for Physics of Complex Systems, Dresden, Germany — [2]Max Planck Institute for Molecular Cell Biology and Genetics, Dresden, Germany

Establishment of cell polarity in the early stages of embryonic development is necessary for unequal cell division and a prerequisite for differentiation in developing organisms. In the zygote of the nematode *Caenorhabditis elegans*, the acto-myosin cortex plays a critical role in polarity establishment. A local down-regulation of myosin activity at the posterior of the zygote triggers directed cortical flow toward the anterior. As the structure and dynamics of the cortex are poorly understood at the microscopic level, we use a coarse hydrodynamic description of the cortex to determine what essential bulk properties are necessary for observed macroscopic flow behavior. We find that on the time scale of the flows, the cortex may be modeled as a viscous fluid that consumes energy through ATP hydrolysis. This simple description gives flow profiles that agree with experimental measurements, suggesting that while they may have other biological significance, more detailed microstructural features are not essential for establishment of cortical flow.