DY 70: Microswimmers, Active Liquids - Part III (joint session CPP/ BP/ DY)

Time: Friday 9:30–11:30 Location: C 264

Invited Talk DY 70.1 Fri 9:30 C 264

From chemical nanomotors to biological microswimmers — •Peer Fischer — Max-Planck-Institut für Intelligente Systeme, Heisenbergstr. 3, 70569 Stuttgart — Institut für Physikalische Chemie, Universität Stuttgart, Pfaffenwaldring 55, 70569 Stuttgart

Building, powering, and operating structures that can navigate complex fluidic environments at the sub-mm scale is challenging. Moving through fluid environments at the scale of micro-organisms for instance presents a different set of challenges compared to those encountered by macroscopic swimmers. Artificial means of realizing motion in microparticles often makes use of local gradients that are established across the colloid, resulting in slip velocities at the particle surface, which in turn drives the motion. In its simplest form this can be realized with Janus-like colloids. I describe what, to the best of my knowledge, are the smallest synthetic chemical nanomotors that have been made and show that their active motion can be tracked with light scattering. Moving from enhanced diffusion to propulsion, I present recent results where colloidal nanopropellers can be moved in water by external magnetic fields similar to a bacterial flagellum and show how the motion of these structures can benefit from the complex rheology in biological media. Although strong Brownian forces dominate in water we achieve controlled propulsion in biological gels, which paves the way for applications inside biological media and the extracellular matrix. Finally, I present an example of a microscallop that does not move in water, but that swims in non-Newtonian liquids.

DY 70.2 Fri 10:00 C 264

Optothermal Manipulation of Plasmonic Nanoparticles in Viscous Solvents — •Felix Winterer[1,2], Christoph Maier[1,2], Theobald Lohmüller[1,2], and Jochen Feldmann[1,2] — [1]Photonics and Optoelectronics Group, Ludwig-Maximilians-Universität München, Munich, Germany — [2]Nanosystems Initiative Munich (NIM), Munich, Germany

We present an all-optical approach to move and manipulate single plasmonic nanoparticles with high accuracy in viscous solvents.

Gold nanoparticles are subject to optical forces and heat generation upon irradiation with a focussed laser beam. Tuning the laser wavelength with respect to the plasmon resonance frequency allows for switching between repulsive and attractive optical forces, which renders it possible to trap or push individual nanoparticles in two and three dimensions. At the same time, laser light can induce heat in the surrounding medium.

We explore how both effects can be employed to control nanoparticle movement by a combination of thermal gradients and optical forces and discuss further applications of this approach for nanolithography and nanoscale physics.

DY 70.3 Fri 10:15 C 264

Dynamics of a carpet of self-propelled surfactant particles covering a liquid film — Andrey Pototsky[1], •Uwe Thiele[2], and Holger Stark[3] — [1]Department of Mathematics, Swinburne University of Technology, Hawthorn, Victoria, 3122, Australia — [2]Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster, 48149 Münster, Germany — [3]Institut für Theoretische Physik, Technische Universität Berlin, 10623, Berlin, Germany

We consider a carpet of self-propelled surface-active particles that move along the liquid-gas interface of a liquid film on a solid substrate and whose swimming direction changes in time due to rotational diffusion. We study the intricate influence of these self-propelled insoluble surfactants on the stability of the film surface and show that depending on the strength of in-surface rotational diffusion and the absolute value of the in-surface velocity several instability modes can occur [1]. In particular, the rotational diffusion can have a stabilizing or destabilizing influence and may even suppress the instability entirely. In the limit of purely upwards swimming we recover the destabilisation described in the literature [2]. The results of the linear analysis are confirmed by fully nonlinear simulations of the complete continuum model and as well through a hybrid discrete self-propelled surfactant particles - continuous film model. [1] A. Pototsky, U. Thiele and H. Stark, Phys. Rev. E **90**, 030401(R) (2014). [2] S. Alonso and A.S. Mikhailov, Phys. Rev. E **79**, 061906 (2009).

DY 70.4 Fri 10:30 C 264

Tangled Flagella: Importance in Bacterial Propulsion — •Tapan Chandra Adhyapak and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, D - 10623 Berlin

It has been well established that hydrodynamic interactions between flagella of peritrichous bacteria such as E. coli, leads to synchronization of rotation and bundling of those flagella [1,2]. Flagella are rotated at their bases by rotary motors embedded in the cell body. In response, the cell body has to rotate in the opposite sense such that total torque acting on the bacterium is zero. Often, such cell rotation causes flagella to tangle before they are synchronized completely. We show that tangling has a profound effect on the overall synchronization and bundling dynamics. In particular, we observe abrupt synchronization and bundling on time scales much shorter than those required when the cell movement is switched off to avoid entanglement. Although hydrodynamic interactions still play an important role, through a comparative investigation we conclude that flagellar entanglement generated by cell rotation predominantly affects the total time to synchronize and bundle. Cell movement modifies stationary bundling states too. Specifically, the length over which a bundle is closely pact varies over time, having an oscillatory behavior whose amplitude decreases with increasing number of flagella. At the end we discuss how strongly all these findings affect the overall propulsion of the bacterium.

[1] M. Reichert and H. Stark, Eur. Phys. J. E **17**, 493 (2005).
[2] S.Y. Reigh, R.G. Winkler, and G. Gompper, Soft Matter **8**, 4363 (2012).

DY 70.5 Fri 10:45 C 264

Reorientation of passive Janus type swimmer in an external temperature profile — •Andreas Bregulla and Frank Cichos — University of Leipzig, department for experimental physics, leipzig, germany

Swimming on the micrometer length scale is dominated by omnipresent Brownian fluctuations and overwhelming viscous forces. Self-phoretic swimmers are an example how to overcome those limitations. Most of those particles are driven by phoretic surface flows generated by surface gradients. In the last decade many different phoretic swimming mechanisms have been proposed. When such self-propelled objects are starting to interact at higher densities, coherent collective motions are observed in which the swimmers align and form flocks, swarms or other complicated patterns. About the origin and details of these complex interactions only little is known. The lack of understanding is mostly due to the lack of control of such particles. Here we want to present a method which extends the existing photon nudging algorithm to gather and collect a specific number of particles and study their interactions. The interactions themselves can be mediated through many different aspects like charges, flow fields or through external profiles created by each active swimmer. The last mentioned interaction will be discussed in detail. An immobile gold colloid acts as an external heat source and mimics the temperature profile that an active swimmer would create in its surrounding. The motion of a passive Janus particle in this temperature field is investigated and the relative motion and alignment with respect to the heat source is quantified.

DY 70.6 Fri 11:00 C 264

Thermophoretic Trapping of Single and Multiple Nano-Objects by Actively Controlled Temperature Fields — •Marco Braun and Frank Cichos — Molecular Nanophotonics, Fakultät für Physik und Geowissenschaften, Universität Leipzig, Deutschland

The understanding of nano-scale soft-matter science benefited enormously from the ability to study single molecules, such as DNA or proteins. In solution Brownian motion lets a molecule disappear quickly from the observation volume, which is why it is typically immobilized in a polymer matrix or by chemical interactions, generally accepted due to a lack of alternatives. However, this strongly changes the local physical and chemical properties. Here, we present an all-optical technique to trap single nano-objects in solution which exploits highly localized temperature fields. The so-called thermophoretic trap exploits thermophoretic interactions of a particle with a temperature gradient, which e.g. locally distorts the screening of the surface charges and by that induces a drift of the particle. In our approach the tempera-

ture field is generated by an optically heated gold nano-structure. Due to the small dimensions of the heat sources, even a small temperature increase introduces large temperature gradients causing a strong thermophoretic drift by which the motion of a Brownian particle can be manipulated. In our experiment an appropriate gold structure is heated locally by a focused laser beam with feedback to the Brownian particles position. The real-time control of the laser beam thereby allows for arbitrary effective trapping potentials for single and multiple particles.

DY 70.7 Fri 11:15 C 264

Low-tech, high-throughput tracking of bacteria in 3D — •Katja Taute, Sander Tans, and Tom Shimizu — FOM Institute AMOLF, Science Park 102, Amsterdam 1098XG, The Netherlands

Many bacteria swim in liquids and execute complex motility patterns. The increasingly recognized diversity of motility strategies has sparked a growing interest in their characterization via 3D tracking. The only 3D tracking techniques thus far to have passed the benchmark of resolving the model bacterium E. coli's run-tumble motility suffer from being limited to single individuals [1]; and/or are technically challenging and require specialized experimental setups [1,2,3].

Here we present a broadly applicable high-throughput 3D bacterial tracking technique which requires only a standard biological phase contrast microscope. We exploit the relationship between an object's distance to the focal plane (z) and the observed intensity pattern, and assign z positions by maximizing image cross-correlations to a reference stack. We achieve micron-scale resolution in z, <0.5 μm resolution in x and y, a range of ~350x300x200 μm (x,y,z), a throughput of tens of bacteria, and a temporal resolution that is only limited by the detector readout rate. We demonstrate the application of this technique to a range of bacterial species, verify that we recover previously observed motility patterns, and reveal that bacterial individuality, rather than stochasticity, underlies the broad population distribution observed for a key motility parameter of V. alginolyticus.

[1] Berg & Brown, Nature 239:500, 1972. [2] Vater et al., PLoS ONE 9:e87765, 2014. [3] Molaei et al., PRL 113:068103, 2014.