DY 61: Microfluidics (joint session DY/CPP)

Time: Friday 10:00–12:15 Location: H6

DY 61.1 Fri 10:00 H6

Tunable stirring of the interior of biofluid microdroplets in a microfluidic channel — •Pierre-Yves Gires, Mithun Thampi, and Matthias Weiss — Experimental Physics I, University of Bayreuth, Germany

Studying dynamic changes of and within fluid droplets with biomimetic or biological composition, e.g. produced in microfluidic devices, is a key technique for biotechnology. However, due to their small dimensions, a controlled and gentle stirring of the droplets' interior has been very challenging. Here we report on an approach that allows for performing such a tunable stirring of microdroplets via home-made magnetic nano-stir bars. In particular, we have used a PDMS-based microfluidic junction with a hydrophobic carrier fluid to produce aqueous biofluid droplets with 10-100 microns diameter into which magnetic nano-stir bars were incorporated. By subsequent stimulation with an alternating magnetic field, nano-stir bars performed a rotational motion with tunable frequencies in the range 0.01-10 Hz. The differential effect of this stirring on particle diffusion and on the undulation of semiflexible biofilaments, i.e. microtubules, was then quantified via quantitative fluorescence microscopy to dissect thermal and active noise contributions.

DY 61.2 Fri 10:15 H6

Soft particles in inertial microchannel flow — •Christian Schaaf and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, Berlin, Germany

Particles immersed in an inertial microchannel flow at intermediate Reynolds numbers move towards discrete equilibrium positions in the channel cross section. This Segré-Silberberg effect can be explained by the inhomogeneous shear profile of Poiseuille flow and particle-wall interactions. While rigid particles assemble around halfway between channel walls and channel center, deformable capsules move closer towards the center [1]. In addition to this lateral inertial focusing, rigid particles at low densities also assemble on 1D lattices along the flow [2]. In this contribution we aim to understand how the deformability of elastic capsules influences the lattice formation and what novel structures now develop.

To study this problem we conduct lattice-Boltzmann simulations. As a first step we focus on the dynamics of a flowing particle pair and see how inertia changes the dynamics of a pair of deformable capsules. For a pair of rigid particles we have recently found that the dynamics is dominated by viscous forces at small distances and by inertial forces at larger distances [3].

In the end these results are used to explain the behavior of soft particle trains and to analyze their dynamics and stability.

DY 61.3 Fri 10:30 H6

Focusing and splitting of particle streams in microflows via viscosity gradients — •Matthias Laumann and Walter Zimmermann — University of Bayreuth, Germany

Microflows are intensively used for investigating and controlling the dynamics of particles, including soft particles such as biological cells and capsules. A classic result is the tank-treading motion of elliptically deformed soft particles in linear shear flows, which do not migrate across straight stream lines in the bulk. However, soft particles migrate across straight streamlines in Poiseuille flows. In this talk we present a new mechanism of cross-streamline migration of soft particles. If the viscosity varies perpendicular to the stream lines then particles migrate across stream lines towards regions of a lower viscosity, even in linear shear flows. An interplay with the repulsive particle-boundary interaction causes then focusing of particles in linear shear flows with the attractor stream line closer to the wall in the low viscosity region. Viscosity variations perpendicular to the stream lines in Poiseuille flows leads either to a shift of the particle attractor or even to a splitting of particle attractors, which may give rise to interesting applications for particle separation. The location of attracting streamlines depend on the particle properties, like their size and elasticity. The cross-stream migration induced by viscosity variations is explained by analytical considerations, Stokesian dynamics simulations with a generalized Oseen tensor and Lattice-Boltzmann simulations.

DY 61.4 Fri 10:45 H6

Synchronization between two boiling bubbles — •Claus-Dieter Ohl[1,2], Dang Minh Nguyen[1,2], Muttikulangara Swaminathan Sanathanan[3], Jianmin Miao[3], and David Fernandez Rivas[4] — [1]Otto-von-Guericke University, Institute for Physics, Magdeburg. — [2]School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore. — [3]School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore. — [4]Mesoscale Chemical Systems, Faculty of Science and Technology, University of Twente, Enschede, The Netherlands

Acoustically driven bubbles are nonlinear oscillators showing a wide range of behaviours such as period-doubling bifurcations, deterministic chaos, and synchronization to an external signal. Here we demonstrate that bubbles driven with a constant heat source can couple with each other and yield in-phase synchronization, even in the absence of an external sound field. Besides perfect synchronization we resolve the parameter space where independent oscillations and bubble merging occurs. The main finding that only weakly oscillating bubbles synchronize provides a path for experimental scale-up to study spatiotemporal synchronization. In the wider scope the findings are relevant for heat transfer applications from structured heaters where complex multi-bubble oscillations are expected.

DY 61.5 Fri 11:00 H6

Dissipative particle dynamics simulation for viscosity behavior induced by self-assembly of surfactants confined in nanotubes — •Yusei Kobayashi and Noriyoshi Arai — Kindai University, Higashiosaka, Japan

Self-assembly is one of the most studied branches of materials chemistry, and has attracted a lot of attention due to its diverse potential applications in electronics, engineering, biomedical, and optical fields. Thus far, many previous studies have reported on the self-assembly of surfactants in solution for developing various functional materials. On the other hand, the chemical nature of the wall surface on the nano/micro scale is another key parameter which can drastically change the self-assembled structures. To study such wall-induced effects on the self-assembled structures and their rheological properties, we performed computer simulations of surfactant solutions in chemically distinct nanotubes under pipe flow. In particular, we determined the shear viscosity as a function of (local) shear rate in hydrophilic, hydroneutral, and hydrophobic nanotubes at different surfactant concentrations. Here, we found that the addition of surfactant molecules led to characteristic viscosity behaviors with rich steady-state morphologies.

15 min. break

DY 61.6 Fri 11:30 H6

Particle trajectory entanglement in confined fluidic systems — •Alvaro Marin[1], Massimiliano Rossi[2], and Christian J. Kähler[2] — [1]Physics of Fluids, University of Twente, The Netherlands — [2]Bundeswehr University Munich, Germany

Suspensions in motion can show very complex and counterintuitive behavior, particularly at high concentrations. However, in this work we show how suspensions at substantially lower dilute concentrations can develop complex dynamics. Such non-trivial dynamics appear when particles tend to interlace their trajectories, only bonded by hydrodynamic interactions. Using a fairly simple system of non-Brownian particles flowing in a confined channel, we reveal a rich complexity in the particle dynamics due to the dominance of short-range particle-particle and particle-wall hydrodynamic interactions. Such rich dynamics are revealed and studied via experiments and particle dynamics simulations, resulting in a very good quantitative comparison.

DY 61.7 Fri 11:45 H6

Aligning beads with boxing gloves — •Archit Bhatnagar[1], Anatol Fritsch[1], Matthäus Mittasch[1], Michael Nestler[2], Matthias Loidolt[1], Axel Voigt[2], and Moritz Kreysing[1] — [1]MPI of Cell Biology, Dresden — [2]Department of Mathematics, TU Dresden

Recently we have described that we can move the cytoplasm of cells and developing embryos in a non-invasive manner. For this we made use of thermoviscous flows (1).

Here we ask the question if these long-ranged flow fields can in principle also be used for the precision alignment of colloids, an endeavor that seems as reasonable as trying to align small beads while wearing boxing gloves. Simulations, however, suggest that series of flow fields can be found to align multiple colloids at the same time, even if these particles are closely spaced.

We follow this strategy experimentally and will report the feasibility, precision limits due to the brownian motion of particles, and prospects for colloidal physics and applications in biology.

References: (1) Mittasch et al., " Non-invasive perturbations of intracellular flow reveal physical principles of cell organization", Nature Cell Biology 1 (2018)

DY 61.8 Fri 12:00 H6

Anisotropic thermophoresis and thermal orientation of elongated colloids — •Marisol Ripoll and Zihan Tan — Institute of Complex Systems, Forschungszentrum Jülich, Germany

Anisotropic phoresis refers to the different phoretic response that elongated particles can have as a function of their relative orientation with a gradient of temperature or concentration. These effects can further be enhanced when the surface of the system is not homogeneous, case in which an additional phoretic orientation can appear for non-fixed colloids [1]. Investigations are performed by a hydrodynamic mesoscale simulation approach [2]. The anisotropic phoresis can furthermore be applied to the design of phoretic micromachines and micropums, which shows to provide an alternative to the conventional application of external forcing in order to pump fluids at the microscale [3].

[1] Z. Tan, M. Yang, and M. Ripoll, Soft Matter 13, 7283 (2017) Z. Tan, PhD thesis, Universität zu Köln (2018)

[2] D. Lüsebrink, M. Yang, and M. Ripoll, J. Phys.: Condens. Matter 24, 284132 (2012) M. Yang, and M. Ripoll, Soft Matter 9, 4661 (2013)

[3] M. Yang, R. Liu, M. Ripoll, and K. Chen, Nanoscale 6, 13550 (2014); Lab Chip, 15, 3912 (2015)