DY 4: Wetting, Droplets and Microfluidics (joint session DY/CPP)

Time: Monday 10:00–12:15 Location: H19

DY 4.1 Mon 10:00 H19

Lattice Boltzmann simulations of dense suspensions of soft particles with interface viscosity — •Fabio Guglietta[1], Othmane Aouane[1], Francesca Pelusi[1], Marcello Sega[1], and Jens Harting[1,2] — [1]Helmholtz Institute Erlangen-Nürnberg, Germany — [2]Department of Chemical and Biological Engineering and Department of Physics, FAU Erlangen-Nüremberg, Germany

Interface viscosity (IV) plays a major role in the dynamics of single droplets and viscoelastic capsules by influencing their transient dynamics and steady-state deformation. For example, it has recently become clear that numerical models for red blood cells must include IV to account for their realistic description. Therefore, IV can be expected to play a significant role in determining also the dynamics and rheology of their dense suspensions. However, as no detailed investigation exists on the effects of IV in the dense suspensions of soft capsules, we aim to fill this gap by including it in computational fluid dynamics models. Here, we address this problem for the first time by performing numerical simulations in the framework of the immersed boundary - lattice Boltzmann method. This approach proved to be a valid numerical tool to provide a realistic description of soft particles immersed in Newtonian fluids. We employ a recent numerical model to account for IV by relying on the discretised Boussinesq-Scriven tensor, which provides a continuum description of a 2D viscous fluid. We show that the IV influences (a) the time it takes for particles to deform during the transient phase and (b) the final shape of the particles in the steady-state at different volume fraction values.

DY 4.2 Mon 10:15 H19

Wetting dynamics of droplets: an immersed boundary lattice Boltzmann approach — •Francesca Pelusi[1], Othmane Aouane[1], Fabio Guglietta[1], Marcello Sega[1], and Jens Harting[1,2] — [1]Helmholtz Institute Erlangen-Nürnberg, Germany — [2]Department of Chemical and Biological Engineering and Department of Physics, FAU, Germany

Many applications in computational fluid dynamics require the immersed boundary (IB) method to couple the dynamics of well-defined structures with that of a surrounding fluid. If the latter is simulated with a lattice Boltzmann (LB) method, the resulting IBLB approach is known to be a very versatile tool, for example, in studying dense suspensions of red blood cells. However, little attention has been devoted so far to applying this approach to substrate wetting problems. Here, we report on an IBLB-based investigation of the wetting of droplets interacting with a solid surface. In our model, the droplet surface tension contributes to the force the droplet (structure) communicates to the surrounding fluid. We characterize Newtonian droplets' static and dynamic contact angles and show how surface/IB-nodes interaction tuning allows obtaining the desired wetting properties. Furthermore, the flexibility of the IBLB approach will enable us to model non-Newtonian surface rheology, opening the possibility of simulating the unusual wetting behavior of gallium droplets. Indeed, liquid gallium develops an oxide layer at the liquid surface when in contact with the oxygen, which affects its adhesive properties with significant consequences for its high-tech applications, such as catalysis.

DY 4.3 Mon 10:30 H19

Viscosity-induced Destabilization of a Liquid Sheet in Inertial Microfluidics — •Kuntal Patel and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, Berlin, Germany

Lab-on-a-chip devices based on inertial microfluidics function between Stokes and turbulent regimes, which enables to achieve high throughput. In the present work, we study the motion of a liquid sheet of thickness t_s and viscosity μ_1 in a two-dimensional microchannel of width w, filled with a viscous fluid (viscosity μ_2, $m = \mu_2/\mu_1 > 1$). At finite Reynolds number Re, a small perturbation at the interfaces separating the sheet from the surrounding fluid can result in a rapid destabilization of interfaces and may lead to a break-up. The present work gives a proof-of-concept of how viscosity-driven interfacial instability can be exploited for a controlled droplet production in inertial microfluidics. Such microfluidic droplets are utilized in food and pharmaceutical related applications and as chemical reactors in Lab-on-a-chip devices.

In our computational linear stability analysis based on the Orr-Sommerfeld equation, we observe that the growth rate of the fastest growing mode ξ^* increases with Re. Furthermore, the dependence of ξ^* on m and t_s is quantified by the scaling law $\xi^* \propto m t_s^{2.5}$, which is valid for thin sheets in moderate Re flows with relatively weak interfacial tension Γ. In the second part, our lattice Boltzmann simulations starting from a single-mode perturbation of wavelength λ reveal that the interfacial instability causes the liquid sheet to break up and ultimately to form droplets when $\lambda \geq 0.5w$. We also identify different interface breakup mechanisms leading to droplet formation.

DY 4.4 Mon 10:45 H19

Imaging, Analysis and Sorting in Microfluidic Systems: Correlative Multi-Contrast, Multi-Parameter Applications — •Tobias Neckernuss[1], Patricia Schwilling[2], Jonas Pfeil[1,2], Daniel Geiger[1], and Othmar Marti[2] — [1]Sensific GmbH — [2]Institute for Experimental Physics, Ulm Univeristy

Droplet-based microfluidics is a promising approach in biology, pharmacy, medicine, and lab-on-a-chip applications. One remaining problem is the lack of a suitable fast image-based detection method that enables droplet- and content-based analysis and sorting with rates fast enough to be sufficient for high-throughput measurements and to enable surveilled lab scale production. We demonstrate recent advances for high-speed, real-time, image-based analysis and manipulation of microfluidic systems. With rates of up to 3000 particles or droplets per second we show applications of our system in the field of droplet-based microfluidics. Here, we concentrate on droplet-content analysis and have a sneak look at further potential applications in biology and image-based cell analysis. We introduce new contrast types for image-based analysis like brightfield, darkfield, phase contrast, fluorescence and combinations thereof. Combining new cutting edge hardware technology with specifically tailored software and integration of external lab infrastructure enables us reach new dimensions in image based particle analysis and sorting.

15 min. break

DY 4.5 Mon 11:15 H19

the obstacle effect on soft sphere discharging in quasi-2D silo — •Jing Wang[1], Kirsten Harth[1,2], Dmitry Puzyrev[1], and Ralf Stannarius[1] — [1]Institute of Physics, Otto von Guericke University Magdeburg, Universitätsplatz 2, D-39106 Magdeburg, Germany — [2]Department of Engineering, Brandenburg University of Applied Sciences, Magdeburger Straße 50, D-14770 Brandenburg an der Havel, Germany

Soft smooth particles in silo discharge show their own characteristics, for example, non-permanent clogging and intermittent flow. We conduct experiment on soft, low-frictional hydrogel spheres compred with hard, frictional spheres in a quasi-2D silo. We introduce a competitive behavior of these spheres during their discharge by placing an obstacle in front of the outlet of the silo. High-speed optical imaging is applied to capture the process of discharge. By the method of particle tracking velocimetry (PTV), the fields of velocity, egress time, packing fraction, and kinetic stress are analysed in the study.

DY 4.6 Mon 11:30 H19

Coalescence of isotropic and nematic droplets in quasi 2D liquid crystal films — •Christoph Klopp, Alexey Eremin, and Ralf Stannarius — Institute for Physics, Otto von Guericke University Magdeburg, Germany

Coalescence of droplets is ubiquitous in nature and modern technology. Various experimental and theoretical studies explored droplet dynamics in three dimensions (3D) and on two-dimensional (2D) solid or liquid substrates, e.g. [1-3]. Here, we demonstrate coalescence of isotropic and nematic droplets in quasi-2D liquids, viz. overheated smectic A freely suspended films. We investigated their dynamics experimentally and measured the shape deformation during the entire merging process using high-speed imaging and interferometry. This system is a unique example where the lubrication approximation can be directly applied, and the smectic membrane plays the role of a precursor film. Our studies reveal the scaling laws of the coalescence time depending on the droplet size and the material parameters. We also compared the dynamics of isotropic and nematic droplets and additionally analyzed the results based on an existing model for liquid lens coalescence on liquid and solid surfaces [4].

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References: [1] J. D. Paulsen et al., Nat. Commun., 5, 3182 (2014) [2] D. G. A. L. Aarts et al., Phys. Rev. Lett., 95, 164503 (2005). [3] N. S. Shuravin et al., Phys. Rev. E, 99, 062702 (2019) [4] C. Klopp et al., Langmuir, 36, 10615 (2020)

DY 4.7 Mon 11:45 H19

Using feedback-controlled thermoviscous flows to precisely position microparticles — •Elena Erben, Antonio Minopoli, Nicola Maghelli, Benjamin Seelbinder, Iliya D. Stoev, Sergei Klykov, and Moritz Kreysing — Max Planck Institute of Molecular Cell Biology and Genetics, Dresden, Germany

Optical positioning of microscale objects has proven key for advancing fundamental biological research and holds great potential for other disciplines as well. The most widely used among these methods are optical tweezers which enable the precise control and manipulation of multiple particles. However, they require probes of high refractive index contrast and low absorption and exclude the use of photosensitive samples. Here we present a novel optofluidic technique that leverages optical-control capabilities and the gentle nature of hydrodynamic flows, thus lifting the aforementioned constraints. Our approach is based on optically-induced thermoviscous flows generated by the repeated scanning of a moderately heating infrared laser beam [1]. We have combined thermoviscous flows with feedback control to confine micron-sized particles with a precision of up to 24 nm without exposing them directly to laser light [2]. Recently, we extended this approach beyond single-object manipulation to further enable simultaneous control of multiple particles. With this contribution, we furthermore discuss combinations with implicit force sensing [3] and the potential for future application in and beyond the life science sector.

[1] Weinert et al., *Phys. Rev. Lett.*, 2008; [2] Erben et al., *Opt. Express*, 2021; [3] Stoev et al., *eLight*, 2021.

DY 4.8 Mon 12:00 H19

Active thin films — •Tilman Richter[1], Paolo Malgaretti[1], Stefan Zitz[2], and Jens Harting[1] — [1]Forschungszentrum Jülich GmbH, Helmholtz Institute Erlangen- Nürnberg (IEK-11), Dynamics of Complex Fluids and Interfaces, Cauerstraße 1, 91058 Erlangen, Germany — [2]Roskilde University, Department of Science and Environment, Roskilde, Denmark

Thin liquid films are important for many microfluidic applications such as printing or coating of e.g. printable electronics or photovoltaic cells where a evenly spread thin film of certain properties is of utmost importance. It is well known that a thin film on a solid substrate can be unstable and droplet formation may arise, especially for very thin films. The dynamics of thin liquid films and their instability has been the subject of intensive experimental, analytical, and numerical studies, the latter often based on the thin film equation. We propose a set of newly developed equations for the influence of chemical active colloids suspended in a thin liquid film based on the lubrication approximation, advection-diffusion and, the Fick-Jackobs approximation. For this novel set of equations we perform a linear stability analysis (LSA) that reveals surprisingly interesting dynamics. We identify the subset of parameters for which the thin film becomes stable, as well as a variety of different dominating wave-modes. This allows us to control not only the stability but also the droplet size distribution after film rupture. In order to assess the asymptotic state of the thin film, the LSA results are compared against numerical simulations using the Lattice Boltzmann method.