DY 14: Microfluidics and Droplets - organized by Uwe Thiele (Münster)

Time: Monday 16:00–18:00 Location: DYa

DY 14.1 Mon 16:00 DYa

Near-field acoustic manipulation in a confined evanescent Bessel beam — •Pierre-Yves Gires[1,2] and Cédric Poulain[2,3] — [1]University Grenoble Alpes, CEA LETI — [2]University of Bayreuth, Experimental Physics I — [3]University Grenoble Alpes, CNRS, Grenoble INP, Institut Néel

Microparticles such as cells can be manipulated in a suspension by the application of an ultrasonic acoustic field. Following the path taken in the development of optical tweezers, we demonstrate the potential of working in the evanescent regime, with both sub-wavelength confinements and resonators [1]. We generate an evanescent acoustic Bessel beam in liquid above a thin, circular, axisymmetrically excited plate. In the sub-MHz domain, the resulting radiation force causes the particles to assemble at the pressure antinodes along concentric circles corresponding to the Bessel profile. By imposing an axial confinement in the evanescent region, the sub-wavelength two-plate sandwich system becomes resonant, increasing the radiation force magnitude. Resonances occur for some well-defined gaps for which whole numbers of antinodal circles are observed. Through fine tuning, particles as small as bacteria can be patterned. Further amplification can be obtained by trapping a microbubble in the Bessel beam axis. [1] Pierre-Yves Gires and Cédric Poulain. Near-field acoustic manipulation in a confined evanescent bessel beam. Communications Physics, 2(1):1-8, 2019

DY 14.2 Mon 16:20 DYa

Actuation of soft particles in oscillating Poiseuille flow — •Winfried Schmidt[1], Sebastian W. Krauss[2], Andre Förtsch[1], Matthias Laumann[1], Matthias Weiss[2], and Walter Zimmermann[1] — [1]Theoretische Physik 1, Universität Bayreuth, 95440 Bayreuth, Germany — [2]Experimentalphysik 1, Universität Bayreuth, 95440 Bayreuth, Germany

What is the dynamical behavior of soft particles in oscillatory (pulsating) Poiseuille flow at low Reynolds number? By investigating the overdamped motion of 2D bead-spring models, as well as 3D capsules and red blood cells, we predict particle actuation in the case of vanishing mean flow. This effect is generic as it does not depend on the model. We show that symmetric particles propagate for asymmetric flow oscillations with non-equal flow sections. The mean actuation (swim) velocity of a particle is caused by its varying shape in both parts of the flow period. Since the actuation steps depend also on the size and the rigidity of soft particles, this novel actuation (passive swimming) mechanism is also appropriate for particle sorting.

DY 14.3 Mon 16:40 DYa

Two orders of magnitude boost in the detection limit of droplet-based micro-magnetofluidics — •Julian Schütt[1], Rico Illing[1], Oleksii Volkov[1], Tobias Kosub[1], Pablo Nicolás Granell[1,2], Hariharan Nhalil[3], Jürgen Fassbender[1], Lior Klein[3], Asaf Grosz[4], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., Dresden, Germany — [2]Escuela de Ciencia y Tecnología, UNSAM, Buenos Aires, Argentina — [3]Department of Physics & Institute of Nanotechnology and Advanced Materials, Bar-Ilan University, Israel — [4]Department of Electrical and Computer Engineering, Ben-Gurion University of the Negev, Israel

The detection of magnetic nanoparticles is of major importance in biomedical and biological applications. Here, the trend goes towards improvements of state-of-the-art methods in the spirit of high-throughput analysis at ultra-low volumes. Microfluidics addresses these requirements as it deals with the control and manipulation of liquids in confined microchannels. Sensor elements utilizing the planar Hall Effect (PHE) are exceptionally suited for this conjunction and were already applied in continuous flow microfluidics. We present a sensing strategy relying on PHE sensors in digital microfluidics for the detection of a multiphase liquid flow. We show the detection of nanoliter-sized superparamagnetic droplets with a concentration of 0.58mg/cm3, biased in a geomagnetic field, down to 0.04mg/cm3 in a magnetic field of 5mT. We are convinced that the tracking of microfluidic droplets can greatly contribute to state-of-the-art magnetoresistive sensing with dramatic downscaling of the analyzed volume.

DY 14.4 Mon 17:00 DYa

Theoretical and numerical investigation of an EWOD-driven micro pump — •Sebastian Bohm and Erich Runge — Technische Universität Ilmenau, Theoretische Physik 1, Weimarer Straße 25, 98693 Ilmenau

We show how the EWOD (electrowetting-on-dielectric) effect can be used to realize a micro pump that uses no moveable components at all, as described in [1]. The flow is generated due to the periodic movement of liquid-vapor interfaces in a large number ($\approx 10^6$) of microcavities ($\Delta V \approx 1pl$ per cavity). The total flow resulting from all microcavities adds up to a few hundred nanolitres per cycle. Tesla-Diodes are used as valves to completely forgo on moving parts.
The theoretical description of the pumping mechanism is a challenge due to the coupling of the fluid- and electrodynamics and the intrinsic multi-scale character of the system. The flow in each microcavity can be modelled as multiphase flow with time-dependent wetting properties as boundary conditions. The optimization of the Tesla diodes is also a challenge, as they must produce a reasonable valve action even at small Reynold numbers, which are typical for microfluidics.
A novel time-efficient simulation method for the calculation of the static interface shapes of a liquid-vapor interface in electric fields is presented. With this method, the voltage-dependent volume stroke can be determined efficiently. Topological optimization methods for the design of the Tesla-Diodes are shown. Finally, possibilities for the time-resolved simulation of the entire pumping system are discussed.
[1] Hoffmann, M., Dittrich, L., Bertko, M.; DE11 2011 104 467 (2012)

DY 14.5 Mon 17:20 DYa

Anchoring-dependent flow bifurcation in nematic microflows within circular capillaries — •Paul Steffen[1], Eric Stellamanns[2], and Anupam Sengupta[1] — [1]Physics of Living Matter, Dept. of Physics and Materials Science, University of Luxembourg, Luxembourg — [2]Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany

Capillary microflows of liquid crystal (LC) phases are fundamental to biological and bio-inspired systems. Here we investigate stationary flows of nematic LC within circular capillaries under homeotropic (normal) and uniform planar anchoring conditions, using numerical simulations based on the continuum theory of Leslie, Ericksen and Parodi for the material parameters of 5CB, a single component flow-aligning nematic LC. Instead of the expected unique solution with a director field monotonously approaching the alignment angle for increasing Ericksen numbers, we report a second anomalous solution that emerges above a threshold flow rate, leading to an anchoring-dependent flow bifurcation. For homeotropic surface anchoring, the anomalous director field orients against the alignment angle in the vicinity of the pipe center; while in the uniform planar case, the anomalous director field extends throughout the capillary volume, leading to reduction of the flow speed for increasing pressure gradients. Experimental signatures of the second solutions in each case are found in authors's experimental results, reported previously in Phys. Rev. Lett. 110, 048303, 2013 (homeotropic) and Int. J. Mol. Sci. 14, 22826, 2013 (planar case).

DY 14.6 Mon 17:40 DYa

Characterizing the speed, size and shape of droplets during their flight from an ultrasonic spray coater — •Pieter Verding[1,2], Wim Deferme[1,2], and Werner Steffen[3] — [1]Hasselt University Institute for Materials Research, Diepenbeek, Belgium — [2]IMEC, Diepenbeek,Belgium — [3]Max-Planck-Institut for Polymer research, Mainz, Germany

Ultrasonic spray coating - USSC is a technology offering numerous possibilities, such as depositing ultrathin homogeneous layers up to 20 nm on large scale. However, its application is limited due to the many process parameters which have a large impact on the quality of the coating. For this reason, measuring the droplet size, speed and concentration during the flight from the ultrasonically generated droplet to the substrate, gives insight in how to tune these parameters. Because thousands of droplets are created at the same time, measuring the properties of the droplets during flight is a complicated task. Three different measurement techniques have been developed in and around an USSC setup. Dynamic Light Scattering (DLS) shows, after Fourier transformation, shifted peaks, representing the speed of the droplets. By applying Turbidimetry, it is possible to determine the size of the droplets. Droplets size and speed could be measured and gave comparable results as measured with a High Speed Camera (HSC). Furthermore, it was shown that the size and velocity of the droplets depend on the process parameters. It is therefore concluded from this work that a combination of DLS and Turbidimetry is a valuable alternative to measure droplets during their flight from an USSC.