CPP 28: Micro and Nano Fluidics III: Migration and flow

Time: Thursday 16:30–18:30 Location: C 264

Invited Talk CPP 28.1 Thu 16:30 C 264

Mixing in passive and active microflows — •Arthur V. Straube — Department of Physics, University of Potsdam, Am Neuen Palais 10, PF 601553, D-14415 Potsdam, Germany

Recent progress and numerous applications in medicine, chemistry and biotechnology have witnessed great interest in understanding the fundamental aspects of mixing at small scales. Because of nonturbulent nature of microflows, mixing of small amounts of even passive liquids is a highly nontrivial task. For active flows, where the different liquid substances can additionally react, this problem becomes especially challenging. In this talk we start with the most important achievements of the mixing problem in passive flows and then proceed to the mixing-induced phenomena in active flows.

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Colloidal Particles Operating Microfluidic Devices — •Tobias Sawetzki[1], Sabri Rahmouni[1], Stefan Bleil[1], David W.M. Marr[2], and Clemens Bechinger[1] — [1]2. Physikalisches Institut, Universität Stuttgart — [2]Chemical Engineering Department, Colorado School of Mines

The miniaturization of microfluidic devices has raised the interest of researchers in biology, chemistry, engineering and physics. Nevertheless, the future goal of a fully functional small and mobile device, the 'lab on the chip', has proven to be quite difficult to reach. In our approach we use paramagnetic colloidal particles as *in situ* building blocks for different functionalities such as pumping or mixing of liquids in channel structures on the micron scale. Once arranged by optical tweezers, the colloidal particles are driven by an external magnetic field which rotates in the sample plane and thus exerts a torque on the colloidal clusters. We demonstrate how this approach allows us to create pumps, valves, T-junctions and mixers. In contrast to other approaches, our concept is quite insensitive to the character of the liquid and the channel material and can be easily scaled up or down thus making it a versatile approach for creating microfluidic devices.

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Positive and negative diffusive-like migration of particles using ion specific effects in microchannels — •Lyderic Bocquet[1], Benjamin Abecassis[2], Cecile Cottin-Bizonne[2], Christophe Ybert[2], and Armand Ajdari[3] — [1]University of Lyon and Technical University Munich — [2]University of Lyon — [3]ESPCI, Paris - Saint-Gobain

Developing versatile methods for driving and manipulating macromolecules or biological cells in microchannels is a key challenge for lab-on-a-chip devices. State of the art approaches for particles' manipulation usually require external fields or specifically designed channel geometries. Here we present a passive and very simple method leading to a tunable and efficient migration of particles in the absence of any external field. Using this method the particles are shown to exhibit a diffusive-like motion which is strongly amplified compared to their bare diffusion process. Moreover both spreading and focusing of the particle assembly can be achieved on demand, corresponding to positive or negative diffusive-like migration. While focusing is a priori conflicting with the second law of thermodynamics, it is obtained in the present mechanism by slaving the particle's dynamics to a fast carrier specie, here a dilute salt, via a chemotaxis-like transport phenomenon, diffusio-phoresis. As a proof of principle, both homogeneization and focusing of a colloidal solution in a microchannel are demonstrated, illustrating the potential of this versatile method for microfluidic applications.

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X-ray optics with microfluidics: Stabilization of gas bubbles by surface ordering and freezing — •Yasutaka Iwashita[1], Christian Bahr[1], Ralf Seemann[1,2], and Stephan Herminghaus[1] — [1]MPI for Dynamics and Self-Organization, D-37073 Göttingen — [2]Experimental Physics, Saarland University, D-66041 Saarbrücken

Compound refractive lenses (CRL), which are composed of many lenses of small radii in a row embedded in a solid medium, have been developed as X-ray lenses (A. Snigirev et al. [1]). CRL has numerous advantages as X-ray optics: It is robust, easy to align and to operate, and can be used for hard X-rays.

To broaden the possibilities and functions of CRL, we propose a "dynamic CRL": This is composed of gas bubbles in a liquid as lenses, where the bubbles are generated and flowing consecutively in a microfluidic device. Due to the continuous renewal of the materials, this system leads to a high stability against high X-ray intensities. Furthermore, the variation of bubble shape controlled via flow parameters allows in-situ optimization of the optical properties of the system.

Here we study the stabilization of gas-liquid foam in microfluidic devices by surface freezing of n-alkanes and surface ordering of liquid crystals. These systems have great advantages for dynamic CRL:(i) X-ray transmission is high and (ii) gas bubbles can be stabilized without surfactants. As a result, we succeeded in stabilizing gas-liquid foam by surface freezing and ordering, and in controlling the foam structure.

[1] A. Snigirev, V. Kohn, I. Snigireva and B. Lengeler, Nature 384(6604), 49(1996)

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Droplet-Based Emulsion Microfluidics for Monodisperse Silica Particle Synthesis — •Venkatachalam Chokkalingam[1], Boris Weidenhof[2], Wilhelm F. Maier[2], Stephan Herminghaus[1], and Ralf Seemann[1,3] — [1]Max Planck Institute for Dynamics and Self-Organization, Goettingen, Germany. — [2]Technical Chemistry, Saarland University, Saarbrücken, Germany. — [3]Experimental Physics, Saarland University, Saarbrücken, Germany.

We explore the possibility to produce silica particles from sol-gel chemistry by means of droplet based microfluidics. Aqueous droplets containing tetramethoxysilane (TMOS), solution (A), and ammonia, solution (B), are formed using two individual production units. The droplet production is synchronized at a Y-junction to form regular pairs of droplets containing the solutions A and B, respectively. The sol-gel reaction is started by merging the individual droplets using either electrocoalescence or a geometrical constriction. Mixing within the coalesced droplets proceeds quite efficiently and the gelation time of the sol-gel solution is adjusted to be within few seconds such, that the gel is fully developed when the gel particles are collected outside the microfluidic device for subsequent drying and heat treatment. The resulting silica particles have a diameter of a few micrometers, only. Since the sol-gel process can be used to produce mixed oxides with tailored porosity and pore size, this controlled monodispersed particle production is of potential interest for a broad range of applications in heterogeneous catalysis. Moreover, different volumetric combinations of any two chemicals are a first step towards combinatorial chemistry.

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Vortex formation in travelling wave-driven micropumps — •Richard Stein[1], Magnus Jäger[2], Andreas Münch[3], Alexander Mielke[3], Michael Böttcher[2], Michael Stuke[4], and Claus Duschl[1] — [1]Fraunhofer Institute for Biomedical Engineering (IBMT), Am Mühlenberg 13, 14476 Potsdam, Germany — [2]Saarland University, Faculty Clinical Medicine, Department Medical Technology, Am Mühlenberg 13, 14476 Potsdam, Germany — [3]Weierstraß Institute for Applied Analysis and Stochastics (WIAS), Mohrenstraße 39, 10117 Berlin, Germany — [4]Max Planck Institute for Biophysical Chemistry, Am Faßberg 11, 37077 Göttingen, Germany

Electrothermally driven flows in microfluidic channel systems with integrated electrodes currently attract increased interest due to their potential biomedical applications, e.g. for switchable accumulation of viruses. Recently, an elaborate experimental study of the electrothermal pumping reported on the formation of vortices at the edges of the electrode field [1]. The vortices appeared to be quite robust and may hold great promise for applications, e.g. as a tool for the separation, accumulation and analysis of biological micro- and nanoparticles in microdevices, provided their formation can be controlled reliably.

In our talk, we introduce a 3D model for the fluid flow in microchannels extending the model of [2]. The approach uses the relevant electro-, thermo- and hydrodynamic mechanisms and is systematically derived by asymptotic techniques. Finally, the flow is numerically evaluated.

[1] M. Felten et al., Phys. Fluids 2006, 18, 051707.

[2] A. González et al., J. Fluid Mech. 2006, 564, 415-433.

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Fluid flow induced by temperature waves - a thermome-

chanical pumping mechanism for microfluidics — Franz M. Weinert[1], •Jonas A. Kraus[2], Thomas Franosch[2], and Dieter Braun[1] — [1]Applied Physics and Center for NanoScience (CeNS), Department of Physics, Ludwig-Maximilians-Universität München, Amalienstrasse 54, D-80799 München, Germany — [2]Arnold Sommerfeld Center for Theoretical Physics (ASC) and Center for NanoScience (CeNS), Department of Physics, Ludwig-Maximilians-Universität München, Theresienstrasse 37, D-80333 München, Germany

Recently, flow at the scale of millimeters and below has attracted significant attention, stimulated by the rapid advances to manipulate and to control small-scale devices. Here, conventional pumping encounters major difficulties and a challenge of the field of microfluidics is to provide adequate tools for fluid manipulation at the microscale.

Here we propose a new mechanism that allows to generate net fluid flow by optical control. The thermal expansion of a fluid combined with a temperature-dependent viscosity introduces nonlinearities in the Navier-Stokes equations unrelated to the convective momentum current. With a suitable set-up we demonstrate that nonsteady heating can be employed to induce non-trivial flow patterns at small scales. This novel thermo-mechanical effect is investigated for a thin fluid chamber by a numerical solution of the Navier-Stokes equations and analytically by a perturbation expansion. A demonstration experiment confirms the basic mechanism and quantitatively validates our theoretical analysis.