CPP 12: Focus Session: Feedback Control of Nonlinear Soft and Hard Matter Systems (original: DY, joined by CPP)

Feedback control methods, which are well established in the field of nonlinear sciences, have recently entered new areas such as pattern formation in non-equilibrium soft-matter systems, Brownian transport and quantum transport. The focus session provides a platform for the presentation and discussion of state-of-the-art results and for pointing out open problems in this emerging field. (Organizers S. Klapp and E. Schöll)

Time: Monday 15:00–17:45 Location: HÜL 186

Invited Talk CPP 12.1 Mon 15:00 HÜL 186

Feedback and information processing in stochastic thermodynamics — •Udo Seifert — II. Inst. für Theoretische Physik, Universität Stuttgart

Stochastic thermodynamics provides a framework for describing feedback control of colloidal and molecular systems [1]. A crucial concept is the notion of optimal finite-time protocols that transform a given initial distribution to a given final one in finite time with minimal thermodynamic cost [2]. If additional information becomes available through a measurement of the state of the system, one can thus even extract work from a single heat bath [3]. Fluctuation theorems taking into account this concept of information lead to bounds on the efficiency of such Brownian information machines [4]. These feedback-based schemes will be compared to autonomous information processing as it occurs in cellular sensing [5].

[1] U Seifert, Rep. Prog. Phys. 75, 126001, 2012
[2] T Schmiedl and U Seifert, Phys. Rev. Lett. 98, 108301, 2007
[3] M Bauer, D Abreu, and U Seifert, J. Phys. A 45, 162001, 2012
[4] D Abreu and U Seifert, Phys. Rev. Lett. 108, 030601, 2012
[5] AC Barato, D Hartich, and US, Phys. Rev. E 87, 042104, 2013

Invited Talk CPP 12.2 Mon 15:30 HÜL 186

Thermophoretic trapping and steering of single nano-objects with plasmonic nanostructures — •Frank Cichos[1], Andreas Bregulla[1], Marco Braun[1], and Haw Yang[2] — [1]Molecular Nanophotonics Group, Institute of Experimental Physics I, University Leipzig, 04103 Leipzig, GERMANY — [2]Department of Chemistry, Princeton University, Princeton, NJ 08544-2020, USA

The manipulation of single micro- and nano-particles or even single molecules in solution requires to beat Brownian motion with a mechanism that drives objects into a well defined direction. Such a mechanism is provided by the thermophoretic drift of nano-objects in a temperature gradient as generated by optically heated plasmonic nanostructures. Since these tiny heat sources can be switched optically at high frequencies, they provide new means of feedback controlled optical manipulations. Here we report on two experiments controlling individual particles in solution by such a feedback mechanism. The first experiment employs a self-propelled thermophoretic swimmer that is steered in solution by a real-time feedback of the swimmer orientation and position. This type of feedback controlled actuation predicts an increased positional control with decreasing particle size. The second experiment involves the trapping of single colloids and molecules in feedback controlled dynamic temperature fields. While the actual thermophoretic drift is repelling the object from the heat source, the dynamic switching provides and effective potential well, which can be shaped by the feedback details. Both experiments provide huge perspectives for study of interactions in well defined clusters of nano-objects.

CPP 12.3 Mon 16:00 HÜL 186

Manipulating rheology of colloidal particles at surfaces — •Tarlan A. Vezirov, Sascha Gerloff, and Sabine H. L. Klapp — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany

Colloidal particles under the combined influence of an external driving force and restricted geometry exhibit a wealth of non-linear phenomena, which are relevant in diverse fields such as directed particle transport, sorting mechanisms and friction phenomena at the nanoscale. We perform computer simulations of a confined bilayer system of charged colloidal particles interacting via a combined softsphere- and Yukawa-potential. The model parameters are adjusted according to ludox silica particles, which we have previously studied under equilibrium conditions [1]. As a framework for solving the equation of motion, we employ overdamped Brownian dynamics simulations. Switching on an external shear flow we find, a sequence of states characterised by pinning, shear-induced melting and reentrant ordering into a moving hexagonal state with synchronised oscillations of the particles [1]. By adding an additional feedback equation of motion we are able to stabilise specific properties such as the degree of hexagonal ordering or the shear stress. This opens the route for a deliberate control of friction properties.

[1] S. Grandner and S.H.L. Klapp, J. Chem. Phys. **129**, 244703 (2008).
[2] T. A. Vezirov and S. H. L. Klapp, Phys. Rev. E **88**, 5 (2013).

CPP 12.4 Mon 16:15 HÜL 186

Optimal control of particle separation in inertial microfluidics — •Christopher Prohm and Holger Stark — Institut für Theoretische Physik, Technische Universität Berlin, D-10623 Berlin

At intermediate Reynolds numbers, particles in a microfluidic channel assemble at fixed distances from the channel axis and bounding walls [1]. This Segré-Silberberg effect can be described in terms of an effective lift force acting on the particles. Devices utilizing inertial lift forces for the separation of bacteria and red blood cells have recently been demonstrated [2]. The separation is most efficient for large size differences since the inertial lift force scales with the third power of the particle radius.

Here, we investigate the motion of a colloidal particle in microfluidic channels using mesoscopic simulations [3]. We show how the geometry of the channel influences inertial focussing. We also demonstrate that manipulating the axial or angular velocity of the particle modifies the inertial lift force profile which permits control of the lateral particle position. Finally we apply the theory of optimal control to the problem of particle sorting in inertial microfluidics [4]. We design optimal force profiles that are able to steer particles to desired lateral positions and, most importantly, to separate particles of similar size in a very robust fashion.

[1] G. Segré and A. Silberberg, *Nature*, **189**, 209 (1961).
[2] A. J. Mach and D. Di Carlo, *Biotechnol. Bioeng.*, **107**, 302 (2010).
[3] C. Prohm, M. Gierlak, and H. Stark *EPJE*, **35**, 80 (2012).
[4] C. Prohm, F. Tröltzsch, and H. Stark *EPJE*, **36**, 118 (2013).

15 min. break

CPP 12.5 Mon 16:45 HÜL 186

Time-delayed feedback control of the Dicke-Hepp-Lieb superradiant quantum phase transition — •Wassilij Kopylov[1], Clive Emary[2], Eckehard Schöll[1], and Tobias Brandes[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin — [2]Department of Physics and Mathematics, University of Hull, United Kingdom

We apply the time-delayed Pyragas control scheme to the dissipative Dicke system, modulating it by the difference of photon numbers emitted from the cavity. Using the mean field approach and linear stability analysis we show that this control dramatically affects the states in the primary superradiant regime, creating new limit cycle phases and a rich phase diagram. We also derive an analytical transcendental equation for the boundaries between the different zones in the phase diagram.

CPP 12.6 Mon 17:00 HÜL 186

Time-delayed control of (un)stable steady states in open quantum systems — •Philipp Strasberg and Tobias Brandes — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr. 36, D-10623 Berlin, Germany

We consider the quantum version of classical time-delayed feedback to control (un)stable steady states of a quantum system. The system is then described by a (non-linear) stochastic master equation, which can be mapped to a set of time-delayed stochastic differential equations for the means and a set of a non-linear equations for the covariances. At steady state, the equations for the means are on average the same as for the classical case with a stochastic part coming purely from the quantum measurement and feedback.

Invited Talk CPP 12.7 Mon 17:15 HÜL 186

Feedback control in quantum transport — •Clive Emary — Department of Physics and Mathematics, University of Hull, United Kingdom

Quantum transport is the study of the movement of electrons in structures small enough that the quantum properties of the electron play an important role. Recent "full counting statistics" experiments provide detailed time-resolved information on the stochastic motion of electrons in such structures which, it is proposed, could form the basis of feedback control schemes for quantum transport. Such feedback control has been shown to give rise to many interesting effects such as the suppression of unwanted current fluctuations, the realisation of a nanoelectric Maxwell's daemon and the stabilisation of non-equilibrium pure states.

In this talk I will review these proposals and discuss the effects of delay on such quantum feedback schemes. I will conclude with some perspectives on the use of coherent — as opposed to measurement-based — quantum control strategies in the transport setting.