From Hot Brownian Motion to Self-Propelled Particles

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1. Introduction

Thermal fluctuations drive the motion of particles and molecules in solvents. This erratic motion of Brownian particles can be understood as a continuous interconversion of solvent thermal energy into particle kinetic energy and back mediated by the viscous friction. Accordingly, a fluctuation dissipation relation known as the Stokes-Einstein relation expresses the relation of thermal energy and viscous friction in Brownian motion. As this random jittering motion rules all motions of small particles in liquids, manipulation of particles in liquids on the nanoscale requires beating Brownian motion.

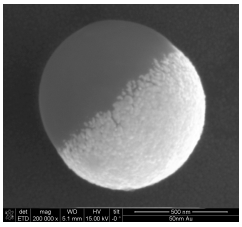

Fig. 1: Electron microscopy image of a Janus particle made out of polystyrene (1µm) with a half-side 50 nm gold coating.

2. Heated particles at a Nanoscale

Here we describe our efforts to manipulate Brownian motion by varying the local temperature as well as the local viscous friction around the diffusing particle. This is implemented by heating gold nanoparticles with focused laser beams. The temperature and viscosity field around the particle modify the conditions of the fluctuation dissipation relation mentioned above and introduce effective temperatures as well as effective friction coefficients [1]. While this concept of Hot Brownian motion of heated nanoparticles relies on radially symmetric temperature and viscosity profiles, Janus type particles with half-side gold coating break the symmetry to cause a net directed transport of particles along the axis of the Janus particle. We demonstrate how these effects can be used to prepare microscale self-propelled swimmers to overcome the randomization of Brownian motion.

3. Conclusion

In summary, we show how to employ local heat sources in liquids to manipulate and overcome Brownian motion of particles, which is a prerequisite for future developments of thermally driven nano-machines.

References

[1] Rings, D, R Schachoff, M Selmke, F Cichos, and K Kroy, Phys. Rev. Lett. 105 (2010) 090604.