diffusion-fundamentals.org

The Open-Access Journal for the Basic Principles of Diffusion Theory, Experiment and Application

Hot Brownian Motion

Daniel Rings, Romy Radünz, Frank Cichos, Klaus Kroy

Universität Leipzig, Fakultät für Physik und Geowissenschaften, Linnéstr. 5,
04103 Leipzig, Germany, E-Mail: rings@itp.uni-leipzig.de

1. Introduction

Brownian motion is an abundant phenomenon throughout the microscopic and mesoscopic world. Since Einstein's seminal work, there is a good understanding of this process under conditions of thermal equilibrium. Brownian motion of particles in inhomogeneous media under non-equilibrium conditions poses important new questions, however. The influence of stationary external fields on particle diffusion has been studied for example in thermophoresis. e.g. [1], but a different aspect, namely the effect of *local* heating of particles on their mobility has not gained so much attention. Recently, Radünz *et al.* [2] have developed a new spectroscopy method, dubbed "Photothermal Correlation Spectroscopy" (PhoCS), which is based on exactly that effect. Thus we derive a theoretical hydrodynamic model to describe "Hot Brownian Motion" of colloidal particles in terms of effective system parameters and a generalized Stokes-Einstein relation..

2. Experiments and Theory

PhoCS is based on the photothermal heterodyne detection of gold nanoparticles as developed by Berciaud *et al.* [3] which exploits the heat released from a light absorbing particle. The resulting temperature gradient in the surrounding solvent can be detected optically due to a change

of the refractive index with temperature. Hence, even nanometer-sized gold tracer particles can be observed by an optical microscope allowing this method to be applied as a substitute for FCS in many cases. As the temperature radially decays around the tracer, the solvent viscosity changes locally, too. By considering a simplified hydrodynamic model, we calculate analytically Stokes' friction on a spherical particle immersed in the prescribed viscosity profile. This leads to the emergence of an effective viscosity, which a homogeneous system would have in order to show the same mobility. Second, we give an expression for the strength of thermal fluctuations deriving from the given temperature profile. Thermodynamic quasi-equilibrium arguments lead us to define an effective temperature, which together with the effective viscosity can be cast into a generalized Stokes-Einstein relation for particle diffusivity.

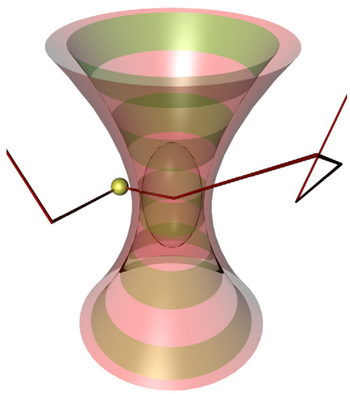

Fig. 1: PhoCS working principle – a colloidal particle enters the focal domain, is heated and the resulting change in solvent index of refraction is detected.

3. Conclusion

We establish the theoretical foundations for the novel spectrocopy technique PhoCS, recently developed by F. Cichos and R. Radünz. A simplified analytic model delivers good predictions of diffusion constants for heated Brownian particles. Thus the method promises to find broad applicability in various fields of physics.

References

[1] F. M. Weinert, D. Braun, Phys. Rev. Lett. **101**, 168301 (2008).

[2] R. Radünz, DR, K. Kroy, F. Cichos, J. Phys. Chem. A **113** (9), 1674-1677 (2009).

[3] S. Berciaud, L. Cognet, G. A. Blab, B. Lounis, Phys. Rev. Lett. **93**, 257402 (2004)