

Evanescent light scattering Optical Tweezers

Aurel Müller-Schoenau, Leon Oleschko
Supervised by Krishna Kumar, Karthika
13.11.2024

Physikalisches Fortgeschrittenenpraktikum 2
Universität Konstanz

Abstract auf Englisch (10-15 Zeilen) Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

1 Introduction

1.1 Physical Principles

kompakten Zusammenstellung der physikalischen Grundlagen

2 Methods

Mit einer Skizze des Versuchsaufbaus

3 Procedure

4 Results

All recorded data and the analysis is available at www.github.com/leoo100/fp2.

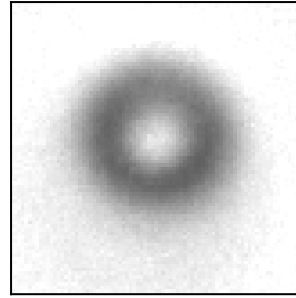


Figure 1 Transmission light microscopy of a observed particle. The radius of the particle is $14(2)$ px, equivalent to $1.86(27) \mu\text{m}$.

4.1 Transmission Light Microscopy

In the first section of the experiment, the particles were observed using a transmission light microscope setup. For this images with a resolution of 600×800 px were recorded with a frequency of 10 Hz for 10 min. The magnification of the microscope was assumed to be $0.133\,196\,72 \mu\text{m}/\text{px}$ [1], this is the main systematic error of this measurement procedure.

The images were normalized with a black (illumination off) and white (illumination on, particle not in frame) reference image, to remove the influence of dust in the imaging elements. The particle that was used for this experiment is shown in Figure 1, after the normalization.

To determine the trajectory of the particle, a effective center of mass was calculated for each frame:

$$\vec{r}(t) = \iint \vec{r} \cdot (1 - I(\vec{r}, t))^2 d\vec{r} \quad (1)$$

The density of the resulting trajectory is shown in Figure 2 for different optical trap stiffnesses. The approximate radius of the optical trap of $2.5 \mu\text{m}$ is drawn as a red circle. For the trap stiffness of 0, the particle is free to wander around, for the higher stiffnesses like 1.01 the particle is mostly confined to the trap.

For a weak trap like 0.75 the particle is still mostly confined to the trap, but can escape the linear trap region and randomly wander around. This happened multiple times during the shown measurement.

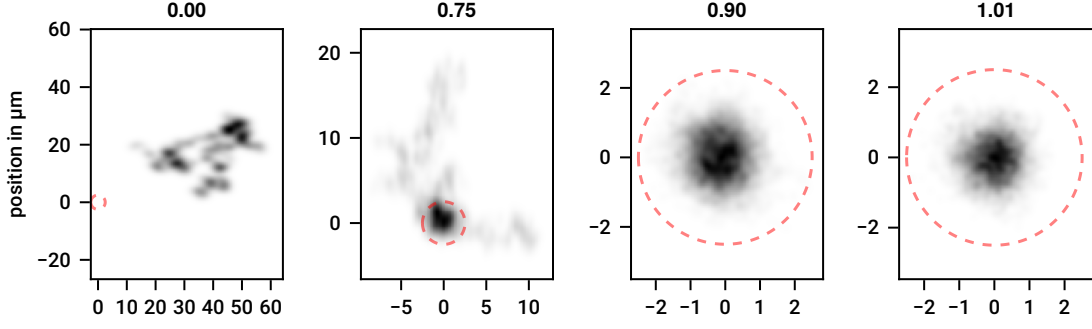


Figure 2 Density of recorded particle positions, grouped by optical trap stiffness. The red circle indicates the approximate radius of the optical trap 2.5 μm .

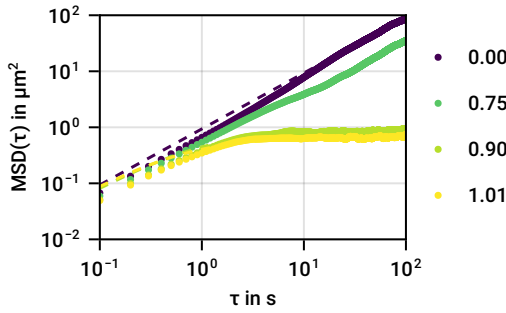


Figure 3 Mean Square Displacement for different optical trap stiffnesses, fit: Equation 3

Mean Square Displacement

A method to describe the trajectory of a random walk is the mean square displacement (MSD) [2]. This is defined as the average of the squared distance of the particle from the starting point:

$$\text{MSD}(t) = \langle \Delta r^2(t) \rangle = \frac{1}{N} \sum_i^N (x_i(t) - x_i(0))^2 \quad (2)$$

Here a different implementation using the autocorrelation of the velocity was used, to achieve a more stable result. This was implemented by [3]. The resulting MSD for different optical trap stiffnesses is shown in Figure 3.

The MSD can be described by the following model:

$$\text{MSD}(\tau) = \frac{1}{\frac{1}{D_0 \tau} + \frac{1}{\text{MSD}(\infty)}} \quad (3)$$

For a free particle the $\text{MSD}(\infty) = \infty$ and the MSD grows linearly with D_0 over time [1, 2].

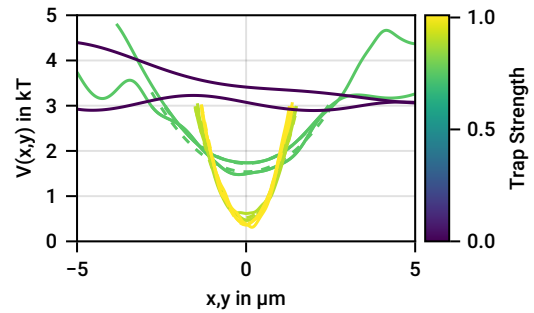


Figure 4 Grouped by axis, relative to mean.

The linear fit for the free particles, works as described with a $D_0 = 0.9357(25) \mu\text{m}^2/\text{s}$. This is roughly equivalent with the expected value of $D_0 = \frac{k_B T}{6\pi\eta r} = 1.22(18) \mu\text{m}^2/\text{s}$ [1], with $r = 1.86(27) \mu\text{m}$ and $\eta = 0.955 \text{ mPa} \cdot \text{s}$.

For a confined particle the MSD reaches a plateau at $\text{MSD}(\infty)$ [1]. For the higher spring stiffnesses (0.90, 1.01), the MSD reaches a plateau and the spring stiffness are shown in Figure 5.

For the lower measured spring stiffness (0.75), the MSD does not reach a plateau, as it partially escapes the trap and wanders around (see Figure 2). Therefore this procedure is not adequate for such low spring stiffnesses.

Potential

The maxwell boltzmann relations [1] are given by

$$P(x) = \exp\left(-\frac{V(x)}{k_B T}\right) \Rightarrow V(x) = -\frac{\log P(x)}{k_B T} \quad (4)$$

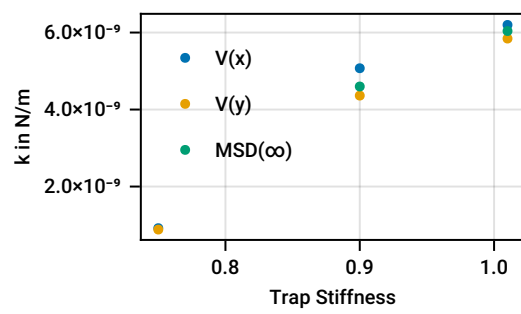


Figure 5 Differently measured spring constants.

4.2 Total Internal Reflection Microscopy

5 Discussion

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

References

- [1] *Evanescent light scattering experiment — Instructions*. Forgeschrittenen Praktikum — University Konstanz. 2023.
- [2] Wikipedia. *Mittlere quadratische Verschiebung — Wikipedia*. 2023. URL: https://de.wikipedia.org/w/index.php?title=Mittlere_quadratische_Verschiebung&oldid=234078066.
- [3] Riccardo Foffi. *MeanSquaredDisplacement*. 2023. URL: <https://github.com/mastrof/MeanSquaredDisplacement.jl>.