

## P22 – Manipulating Microscopic Objects Using Combined Elliptical and Point Optical Tweezers

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Single beam point optical tweezers were modified to manipulate microscopic objects. Idea to this kind of object manipulation came from article written by Mohanty and colleagues [1]. Second line was designed with Zemax optical designing software and built to produce elliptical tweezers with two cylindrical lenses. We used Nd:YAG laser with 1064 nm wavelength. Laser light was split to two lines and combined before objective with polarizing cube beam splitters. Microscope objective was water immersion objective (Olympus LUMPLFL 100X W/1.00). With this new setup single red blood cell could be rotated with combined tweezers by rotating cylindrical lenses. Maximum of seven red blood cells were trapped to the elliptical tweezers simultaneously in PBS solution when optical power in focal plane was ~ 13 mW (figure 1). When optical power was reduced to ~ 5 mW, the last four remaining cells escaped from elliptical tweezers.



**Figure 1: Seven red blood cells trapped in elliptical tweezers.**

[1] Mohanty S.K., Dasgupta R., Gupta P.K. (2005) Three-dimensional orientation of microscopic objects using combined elliptical and point optical tweezers, *Applied Physics B* 81, s. 1063-1066

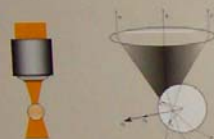
# Manipulating microscopic objects using combined elliptical and point optical tweezers

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## Introduction

Point optical tweezers offer a sophisticated and contactless way of manipulating small particles and single cells. With combined elliptical and point optical tweezers single cells can be rotated around the optical axis and multiple particles and cells can be trapped to the elliptical tweezers simultaneously. This kind of particle manipulation was presented in article written by Mahanty et al. [1]

## Physical principles of optical tweezers



A tightly focused Gaussian laser beam is used to create a strong axial and radial gradient force. A dielectric particle in the laser beam experiences a force towards the centre of the beam, where the light gradient is stronger. The trapped objects can be manipulated by moving a sample stage or by changing different parameters of the trapping beam.

Incident photons induce forces on particles:

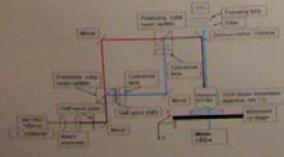
- Gradient force (in the direction of the spatial light gradients)
- Scattering force (in the direction of light propagation)

System requirements:

- Stable laser with TEM<sub>00</sub> or TEM<sub>01</sub> beam profile
- Objective with a high numerical aperture
- Wavelength with poor absorption in both the sample and surrounding medium
- Particle's refractive index is larger than the surrounding medium's

## Measurement setup

- Laser (Viasho VA-II-N-1064), 1064 nm wavelength
- Water immersion objective (Olympus UPLFLN100X 1.00, water) and oil immersion objective (Lomo 90X 1.25, oil)
- CCD-camera (LCL-902K, Watec America Corp.)
- Motorized xy-stage (Thorlabs MAX201)



## Samples

Human red blood cells (max diameter ~7.4 μm [2,3]) were studied in cylindrical cuvette (diameter 34 mm) (Figure 1 (a)) with water immersion objective and TiO<sub>2</sub> microspheres (diameter 0.4 μm, Kemira, Finland) were studied on sample glass (Figure 1 (b)) with oil immersion objective. Human RBCs were studied with PBS (phosphate buffered saline) as a suspension and microspheres with distilled water as a suspension.



Figure 1. (a) Red blood cells were studied in cylindrical cuvette. (b) TiO<sub>2</sub> microspheres were studied on sample glass.



Photo of our measurement system

## Red blood cell in combined tweezers

Red blood cell was trapped mainly to point optical tweezers optical power being ~8 mW in focal plane. Some power was also steered to elliptical line, which caused cells large concave surfaces to align along the elliptical trap major axis. Rotation of cylindrical lenses caused cell to rotate in focal plane (Figure 2). Single particles are easier to rotate with combined tweezers because particle is mainly trapped to point tweezers.

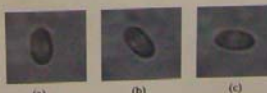


Figure 2. Position of red blood cell in combined optical tweezers. (a) Cell in vertical position. (b) Cell rotated 45 degrees. (c) Cell rotated 90 degrees.

## Red blood cells in elliptical tweezers

Elliptical trap was in the same focal plane with point optical tweezers. Red blood cells could be rotated by rotating cylindrical lenses at the same time (Figure 3). Seven red blood cells were trapped simultaneously in elliptical trap, when optical power in trap was ~47 mW (Figure 4). Same power kept five red blood cells in trap for seven minutes (Figure 5) until sixth cell joined the group. When optical power from five cells group was reduced to ~29 mW, one cell escaped from trap. With this power these four remaining cells moved along the major axis of the elliptical trap due to low power. These four cells escaped from trap, when power was reduced to ~21 mW.

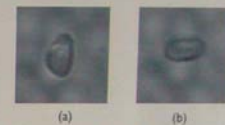


Figure 3. Rotation of red blood cell in elliptical tweezers from vertical (a) to horizontal (b) position.



Figure 4. Seven red blood cells trapped at elliptical line tweezers.



Figure 5. Five red blood cells stayed in trap for seven minutes.

## TiO<sub>2</sub> microspheres in elliptical tweezers

0.4 μm TiO<sub>2</sub> microspheres (SEM-image Figure 6 (a)) were trapped in elliptical tweezers. Microspheres were trapped using Lomo oil immersion objective. Line of microspheres was rotated by rotating cylindrical lenses (Figure 6 (b)-(c)).

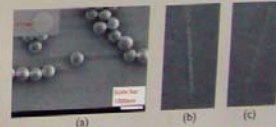


Figure 6. (a) Image of used TiO<sub>2</sub> microspheres. When cylindrical lenses were rotated clockwise, trapped microspheres moved from (a) to (b).

## Conclusions

Red blood cell was trapped in combined tweezers and red blood cells and red blood cells in elliptical TiO<sub>2</sub> microspheres and red blood cells in point and tweezers. Red blood cells were trapped in point and elliptical tweezers with their large concave surfaces parallel to optical axis. Multiple red blood cells and microspheres were trapped simultaneously to elliptical line. In experiments five red blood cells stayed in elliptical tweezers for seven minutes. This time will be longer with less flow in cuvette.

## References

1. Mahanty, R., Dey, S. K., & Sanyal, S. (2002). "Trapping and rotation of colloidal particles and cells using optical tweezers." *Journal of Microscopy*, 107, 1-10.
2. Kinnunen, M., Kauppila, A., & Myllylä, R. (2008). "Simultaneous trapping and rotation of multiple particles using combined elliptical and point optical tweezers." *Optics Express*, 16, 10000-10006.
3. Kinnunen, M., Kauppila, A., & Myllylä, R. (2008). "Simultaneous trapping and rotation of multiple particles using combined elliptical and point optical tweezers." *Optics Express*, 16, 10000-10006.

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