Effect of polarization change in a laser trap for single cell ionization of human red blood cells (RBCs)

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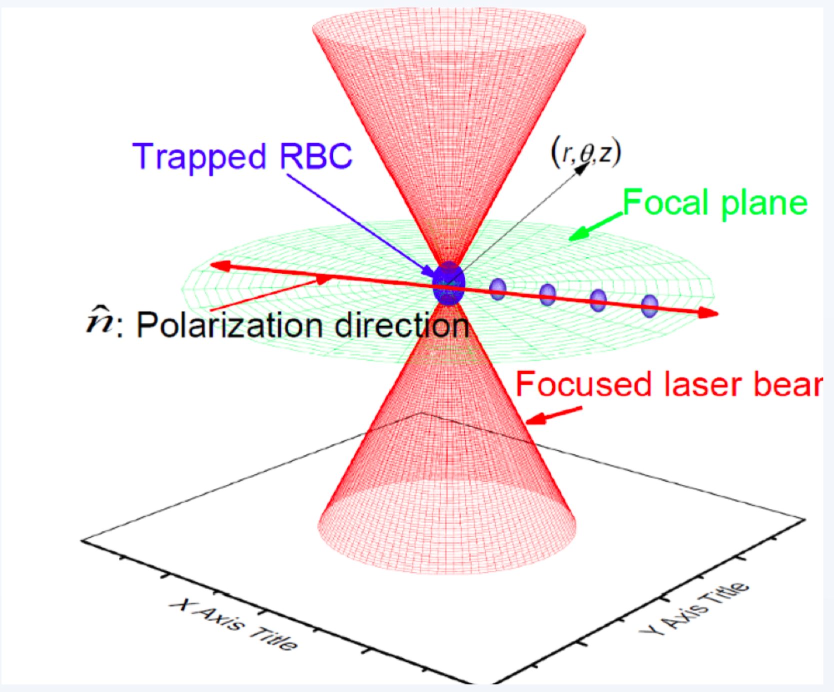
INTRODUCTION

- The laser trapping technique has been used to hold and manipulate microscopic dielectric objects, such as silica beads and human red blood cells (RBCs).
- The RBC can be modeled as a dielectric spherical shell composed of an ionic solution within a phospholipid membrane.
- Theoretically, once in the laser trap, the RBC is acted upon by an electrostatic force, the drag force from the liquid medium, and the trapping force of the laser.
- Silica beads are acted upon by the drag force from the liquid medium and the trapping force of the laser.
- RBCs held by the laser trap will ultimately ionize and eject from the trap at a threshold level of energy.

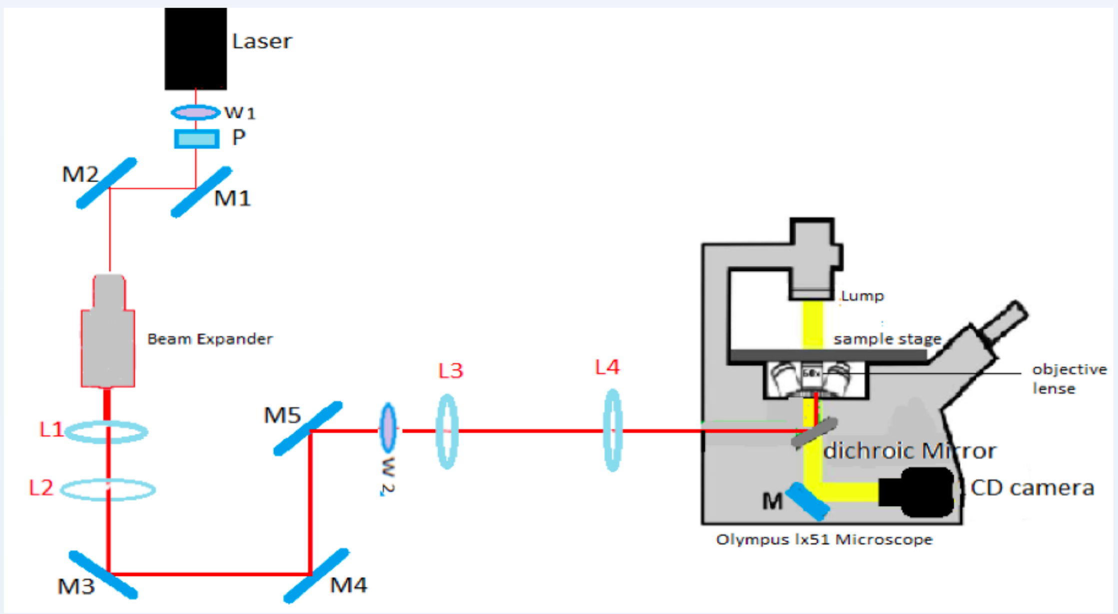


OBJECTIVES

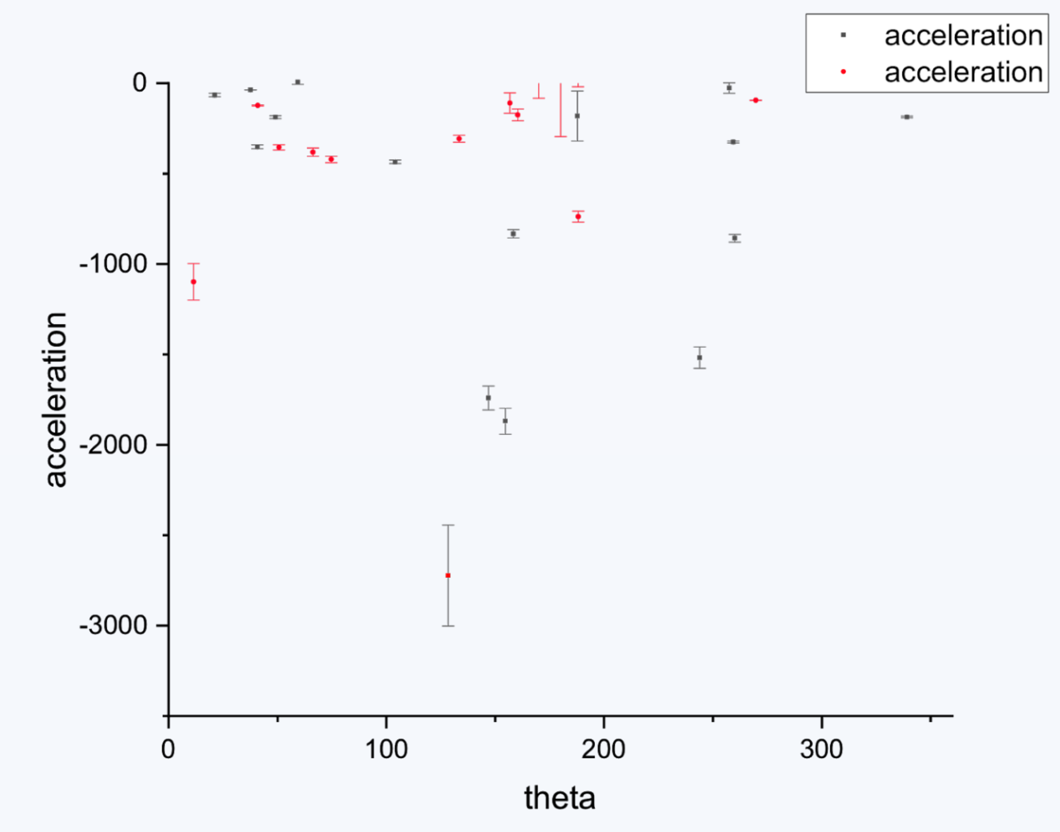
- After the RBC fully ionizes and develops charge, it experiences an electrical force parallel to the polarization direction of the laser. Thus, the RBC is predicted to eject along the polarization direction for a perfectly symmetric trap.
- We seek to verify that the ejection direction of the RBC is along the polarization direction of the laser.
- Furthermore, a prerequisite study was done to test the symmetry of the laser trap since an asymmetrical trap can lead to unequal distribution of trap force that would affect the direction that the cell leaves the trap.

MATERIALS & METHODS

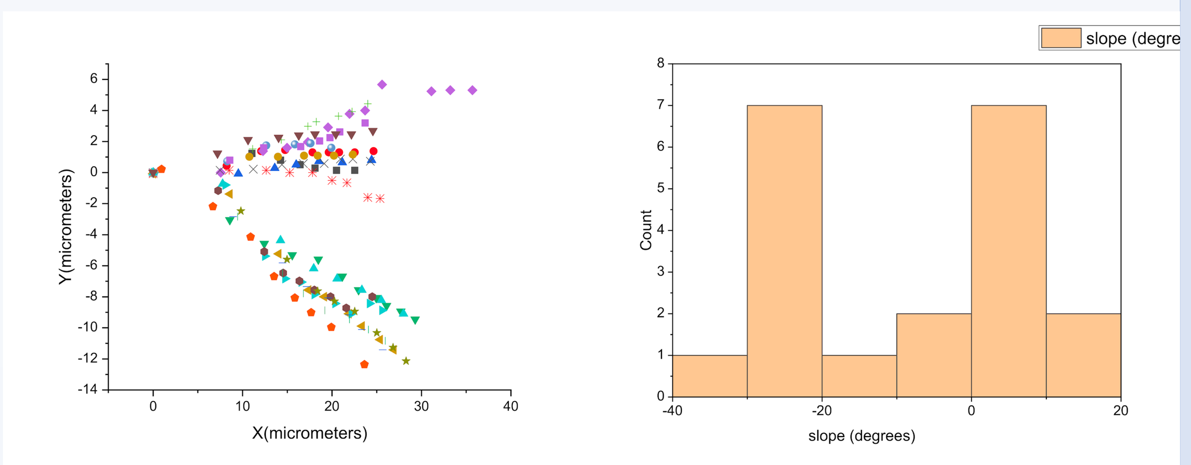
- The experiment used an infrared diode-pumped laser at 1064 nm, generating linearly polarized light with maximum power of 8W and beam size of 4mm. The beam size was altered by the beam expander and lenses (L1,L2) and directed to the microscope using mirrors (M1-M5). The laser entered the microscope and hit a dichroic mirror (DM) at 45° to meet the objective lens and form the laser trap. A computer-controlled camera attached to the microscope captured a sequence of images of the silica beads and RBCs entering and leaving the trap. The images were analyzed using ImagePro, LoggerPro, and OriginPro softwares.
- The experiment was divided into two main parts: laser trap strength symmetry and effect of polarization on single cell ionization.
- In the trap strength study, 3.1 micron silica beads were used and prepared on depression slides. To study the trap strength, the acceleration ($^{\mu m}/_{s^2}$) of the silica beads as they approached the laser trap was compared to the direction (°) they approached the trap.
- LoggerPro was used to determine the X and Y positions (μm) of the silica beads over time. OriginPro was used to perform a nonlinear fit to determine the acceleration.
- To study single cell ionization, RBCs were obtained from Dr. Daniel Erenso. 5-10 μl samples were prepared and diluted to decrease the concentration of RBCs that would appear on the depression slides.
- The polarization direction of the laser was changed by 45° and 90°, using the half-wave plate. RBCs were ejected from the trap for 10 minutes at each polarization direction.
- LoggerPro was used to determine the X and Y positions (μm) of the RBC over time. OriginPro was used to perform a linear fit to determine the slope, or ejection direction of the RBC.



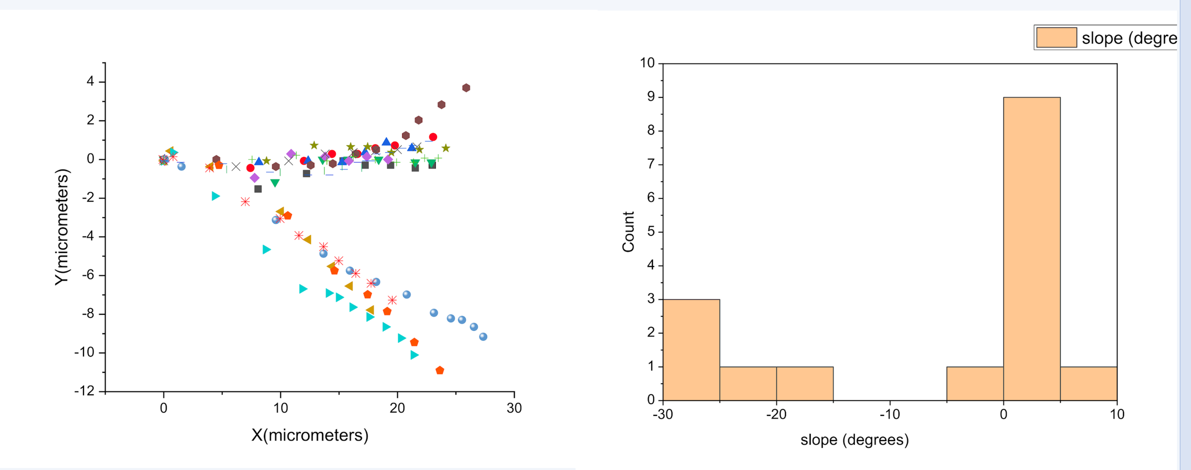
RESULTS



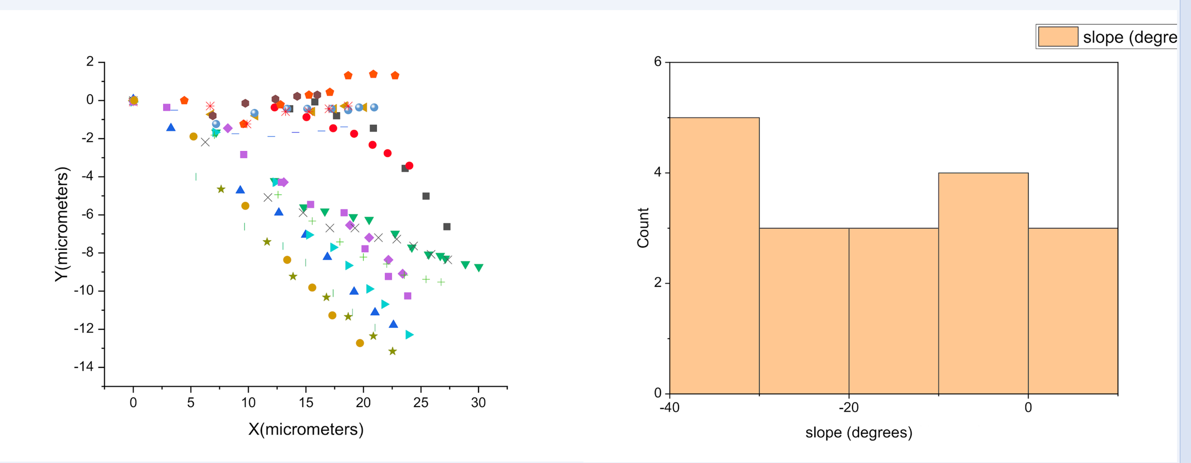
Theta (°) vs. Acceleration ($^{\mu m}/_{s^2}$)



Ejection direction with vertical polarization. HWP at 70°. Average slope: -8°.



Ejection direction with HWP at 47°. Average slope: -6°.



Ejection direction with horizontal polarization. HWP at 24°. Average slope: -16°.

CONCLUSIONS

- Using silica beads, it was shown that the laser trap strength is asymmetrical.
- The trap is stronger in the second and third quadrants. This may influence the ejection direction of the RBCs from the laser trap.
- Results showed that the RBCs ejected into mainly two different directions at each polarization direction.
- In analyzing more data, the ejection at each polarization direction may be more distinct and might match theoretical predictions.
- Otherwise, we may consider the asymmetry of the trap strength or other electrical properties of the cell to explain the ejection directions.

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