Summary

The paper will cover optical tweezers, a method of trapping small (nano to micrometer) particles using laser. The trapped particle is a dielectric bead, typically glass or plastic, with a known refractive index. As the light passes through the bead, the light is refracted across the bead. The light will exit at new angles relative to the incident, exerting a force due to the photon's momentum. If the bead is off-center from the laser's axis, the force will be toward the center axis. This effect can be understood using ray diagrams.

In the paper, I am hoping to discuss:

- Brief introduction: basic description of the optical tweezers and some historical background
- Theory of operation:
    - Askin's first setup - describing its principles using ray diagrams and calculations
    - Then, a lateral trap with a convergent lens
- Experimental setups: typically including a beam expander and a mirror to adjust the location of the incident beam. Not really sure if I fully understand *why* some components are included.
- Applications – mostly in biology

List of Derivations/Calculations

Ray optics diagram—for larger particles, ray diagrams can be used to explain how the particle interacts with the incident light. I'll include the ray (and force) diagrams and the accompanying equations to describe how the basic apparatus balances the forces.

- In Ashkin's original experiment with particles suspended in water, the angle and intensity of the ray path through the sphere can be calculated using geometry and the Fresnel equations.
    - For an unfocused laser (without the converging lens), he considers the light as a radially Gaussian TEM00 source.
    - If the particle is not centered within the laser beam, there is net force to bring the particle to the center, arising from radial gradient of the light.
- Since the particles are suspended in water, Ashkin applies Stoke's law as well, to calculate the friction forces on the sphere.
- As there's a net force in the direction of the light propagation, the particle will begin accelerating. If the laser is underneath the target, it will balance gravity, keeping it stationary--but it's fairly unstable.
    - Later, Ashkin uses a convergent lens between the laser and particle, creating a backward force on the particle (in the text as "backward gradient force"). I don't really understand this part yet but Askin implies it's trivially found through ray diagrams.

Sources

1. Ashkin, A., 1970. Optical trapping and manipulation of neutral particles using lasers. Optics and Photonics News, 10(5), p.41. doi:10.1103/PhysRevLett.24.156
2. Ashkin, A., Dziedzic, J. M., Bjorkholm, J. E., & Chu, S. (1986). Observation of a single-beam gradient force optical trap for dielectric particles. Optics Letters, 11(5), 288. doi:10.1364/ol.11.000288
3. Ashkin, A. and Dziedzic, J.M., 1971. Optical levitation by radiation pressure. *Applied Physics Letters*, *19*(8), pp.283-285. doi:10.1063/1.1653919