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Active Wavefront Correction

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Active Wavefront Correction for Optical Tweezers

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Abstract

We present our preliminary result for the experiment to actively correct the wavefront of a laser used in an optical tweezers set-up. This was done by converting a desired pattern into a phase modulation that a spatial light modulator can display. We developed a program to calculate the phase modulation and interface with the SLM. An SLM is a device that allows for manipulation of pixels to create a custom lens. A laser reflects off of this SLM and its diffraction pattern will be actively monitored with a high speed camera.

The camera allows us to dynamically change the displayed pattern on the image on the SLM so that the resulting diffraction pattern matches that of our desired pattern. This means that the camera could actively monitor and correct for any aberrations that come from our set-up and we will report our progress on this active correction.

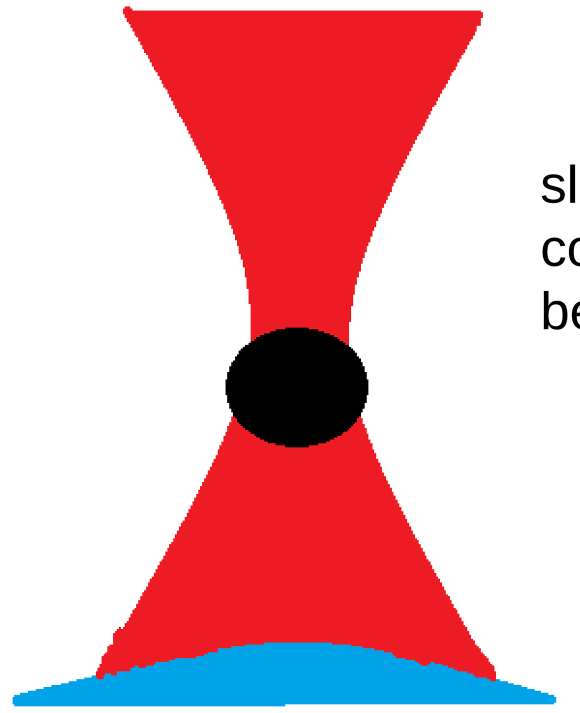
History

First created by Arthur Ashkin in early 1970s. He and his team theorized that micron-sized particles could be displaced and trapped in air or water in three dimensions. He was one of the first to detect optical scattering on micron-sized particles.

In the 1980s, Arthur Ashkin would go on to use the optical tweezers for biological uses. He used the tweezers to trap viruses and bacteria. Other researchers would go on to use the tweezers to trap other biological elements.

How It Works

A high intensity laser is focused by a series of lenses. The particles are trapped near the most focused area of the beam. The trapping occurs as a direct result of ray optics. A photon enters the particle, carrying with it a certain amount of momentum. The photon is emitted from the particle in a different direction than it entered. This results in a change of momentum for the photon, and due to Newton's third law, an equal but opposite change in momentum for the particle. Because of the symmetrical rays of light entering the particle, the net forces along the axial direction are canceled out.

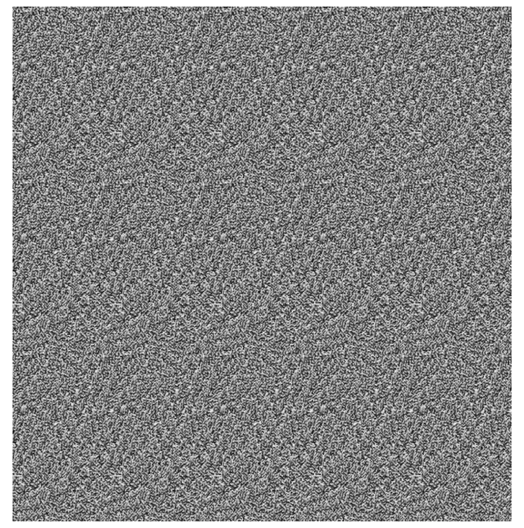


The particle is not trapped exactly at the most focused area. Instead it rests slightly before or after the most focused area. It is however trapped within the confines of the beam along the axial direction. The particle is unable to escape the beam profile.

The ability to create patterns of trapped particles comes from this pieces of equipment, a spatial light modulator (SLM). This SLM is essentially a small LCD screen and allows for images to be displayed on it. This is done by adjusting the width of each pixel on the SLM. By changing the width of a pixel, it changes the index of refraction which then adjust the angle at which the light will reflect off of it.

from: http://en.wikipedia.org/wiki/Spatial_light_modulator

This desired pattern becomes



This pattern is displayed on the SLM and the result is

Fixing the Unfixable

The images that are produced are not perfect. This means that if I were to attempt to trap a group of particles in a square, they would not be in the exact same shape as the pattern that I desired.

This problem arises because of the aberrations in the lens system, the irregularities in the air, and even vibrations through the entire system. To fix this, a monitoring device is implemented. A high speed camera is set-up to monitor the output pattern from the SLM and make adjustments accordingly.