Trapping Microparticles by Mimicking Optical Tweezers with Lensed Fibers

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Abstract

Optical tweezers can trap and manipulate microscale particles using light. A well-collimated Gaussian beam exerts a gradient force on a microparticle and interacts with it through a transfer of momentum. Optical tweezers are useful in areas such as biology and chemistry due to their ability to precisely manipulate microscale objects (e.g., cells). The current methodology to stably trap a particle uses a collimated laser and a high aperture lens; however, the entire size of such an optical tweezer system is bulky and limited to the lab environment only. Our goal is to make optical tweezers more compact by using lensed fibers. A high numerical aperture of the lensed fibers focuses the beam, and provides a restoring force that is necessary to keep the object in a stable trapping. Our method includes making a solution with microparticles, and then applying the microparticle solution into the beam such that a particle falls into the beam cavity and becomes trapped. We expect our trapping setup to be more stable than conventional optical tweezers. Once we determine if trapping is achievable, we hope to quantify the stability of our system by monitoring the Brownian motion of the particle movements through the microscope. Our optical tweezers will be compact and provide a stable trapping capability, and therefore will pave the way toward the on-chip optical tweezer system.

Introduction

The 2018 Nobel Prize in physics went in part to Arthur Ashkin for his work with optical tweezers and their applications in a biological setting. Furthermore, the lensed fiber approach has already been proven successful in additional experiments carried out in liquid solutions. However, we hope to achieve trapping in air with a lensed fiber setup.

In optical tweezers, particle manipulation is determined by the intensity profile of the beam; the particle’s relative position to different intensities will determine the net momentum transfer to the particle. Originally, lenses were used to direct the light such that it converges, and our lensed fiber gives us a Gaussian beam. A beam with a Gaussian intensity profile will have a net restoring force pulling the particle toward the center of the beam. However, the laser’s momentum still pushes the particle forward. To compensate for this and achieve stable trapping, we could either use another laser from the opposite direction (dual-fiber optical tweezers), or continue with single-fiber optical tweezers by using a higher aperture lens. This would put the particle just below the beam’s focus, pulling it back toward the laser and negating the forward force. Thus far, we have only attempted single-fiber methods.

Methods and Results

**Method 1: Open Air**

To achieve trapping in air (rather than in liquid), we created a solution of silicon microparticles that we misted around the fiber tip using a nebulizer (Fig. 3).

For Method 1, we put the solution mist around the tip of the fiber in open air. The result can be seen in Figure 4. The particles stuck to the sides of the fiber itself, but where not trapped by the beam.

**Method 2: A More Controlled Environment**

For Method 2, we tried to make a controlled environment by setting up a beaker around the fiber to block air currents. We then sent the mist from the nebulizer into the beaker around the fiber, as in Figures 5 and 6.

The results can be seen in Figures 7 and 8. Again, trapping was not achieved. Unfortunately, the curved glass of the beaker distorts the view of the fiber. This setup requires improvement for future trials.

Conclusions and Next Steps

All of the trials to this point have failed to produce a trapped particle. There is still too much force from the nebulizer’s mist to achieve a stable trapping. The entire fiber could be seen moving when the nebulizer was used, indicating that the fiber itself is not stable. In addition, the downward gravitational force is also preventing the particles from being suspended. More work is needed to minimalize these external forces. The particles are also clumped together, as seen in Figure 3, making trapping a single particle difficult, and these clumps are too heavy to remain airborne. Our next steps will involve creating a setup where the mist is directed from below to overcome the gravitational forces, and using a sonicator to more evenly distribute the particles in the solution. We are optimistic that by improving the conditions of the setup, a trapping will be achieved. We still hope to quantify the stability of our system and move toward on-chip applications.

References


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