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Dynamic DMD-Driven Optoelectronics Tweezers for Microscopic Particle Manipulation

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Abstract: We demonstrate dynamic manipulation of microscopic particles using a DMD-produced projection image in an optoelectronics tweezers system. Single-particle trapping and movement (up to 40 μm/sec) via optically-induced dielectrophoresis were observed.
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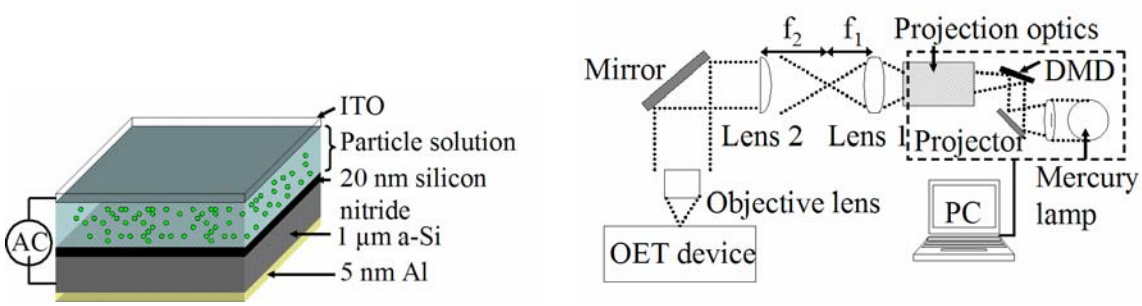
1. Introduction

The ability to move and sort single cells is highly sought after in the biomedical and biological community. Optical tweezers [1], and dynamic holographic optical tweezers (HOT) arrays [2] have provided a means of performing individual cell manipulation, but require high optical power levels (1mW~ 100mW) and have a small trap area (< 1 μm). Optoelectronics tweezers (OET) provides a method of cell manipulation which overcomes the shortcomings of optical tweezers [3]. It requires very low optical power (~ μW), which opens up the possibility of using incoherent light source and direct optical imaging to pattern the traps..

Previously, we had demonstrated OET manipulation of microscopic latex spheres [3] and live *E. coli* cells [4] using a single laser beam. A spatial light modulator can be used to generate multiple OET traps and novel patterns such as line and ring cages. In this paper, we report on novel particle cages capable of trapping and moving micro-particles by using a digital micromirror device (DMD) to project dynamic images onto our OET device, via a standard multimedia projector. *To our knowledge, this is the first demonstration of microscopic particle manipulation using a non-coherent light source.*

2. Optoelectronic Tweezers Principles and Theory

Optoelectronic tweezers is based on optically-induced dielectrophoresis [3]. A light source is focused onto the ac-biased amorphous silicon (a-Si) photoconductive substrate layer of the OET device (Fig. 1a). A buffer solution, sandwiched between the nitride layer and the indium-tin-oxide (ITO) top layer, contains the particles of interest. In the dark, the a-Si is highly resistive. As the photoconductive layer is illuminated, the conductivity of the a-Si is greatly increased, due to photogenerated charge carriers. This creates a localized virtual electrode, and generates a non-uniform electric field in the buffer solution. Dielectrophoretic (DEP) forces result from the electric field non-uniformity. These forces are either positive (particles attracted to electric field maxima) or negative (particles attracted to electric field minima), depending upon the dielectric properties of the particle and the media and the bias frequency [3].



(a) (b)

Fig. 1. (a) OET device structure, and (b) schematic of experimental setup.

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The spatial electric field distribution resulting from a ring pattern projected onto the OET surface can be made to form a single-particle trap (Fig. 2). Negative DEP forces hold a particle in the center of the light ring, as this corresponds to a local electric field minima. Particles outside the ring are repelled by the same forces.

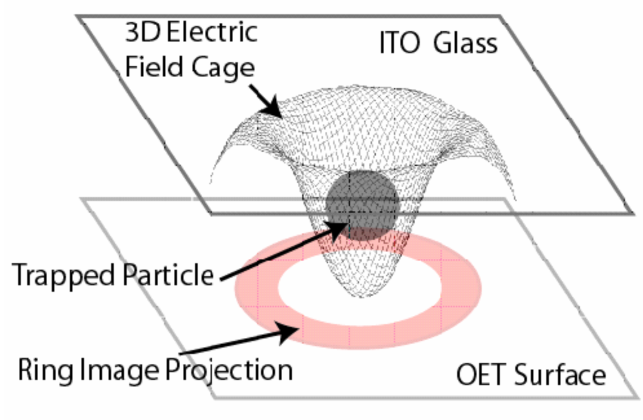
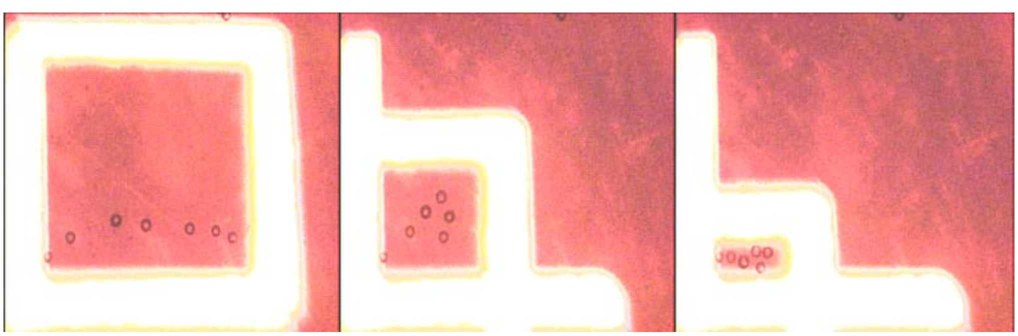


Fig. 2. Electric field distribution for a single-particle ring trap.

3. Experimental setup and results

An InFocus LP335 DMD-based projector was used as both the light source (via its 120-W, 1000-ANSI lumen high-pressure mercury lamp) and as the DMD driver circuit interface (Fig. 1b). The DMD, made of an array of MEMS mirrors [4], forms an image corresponding to the output of the PC's external monitor port. Light at the output of the projection lens was collected, collimated, and directed into a 10X objective lens. The objective focused the beam into the buffer solution with a conductivity of 0.1 mS/m, sandwiched between the ITO top layer and photoconductive bottom layer. The photoconductive layer was situated on the stage of a Nikon TE2000E inverted microscope. Observations were made via a CCD camera coupled into the inverted microscope.

Images were formed on the focal plane of the objective using standard presentation software (Microsoft PowerPoint) on a PC connected to the DMD projector. Negative DEP forces were observed on the 25-µm latex spheres in solution, at an ac bias of 19.5V and a frequency of 100 kHz. A variety of patterns were used to manipulate the particles, including dynamic line cages (Fig. 3a-c) and ring traps (Fig. 3d-f). Particle movement was observed to be approximately 40 µm/sec.



(a) (b) (c)

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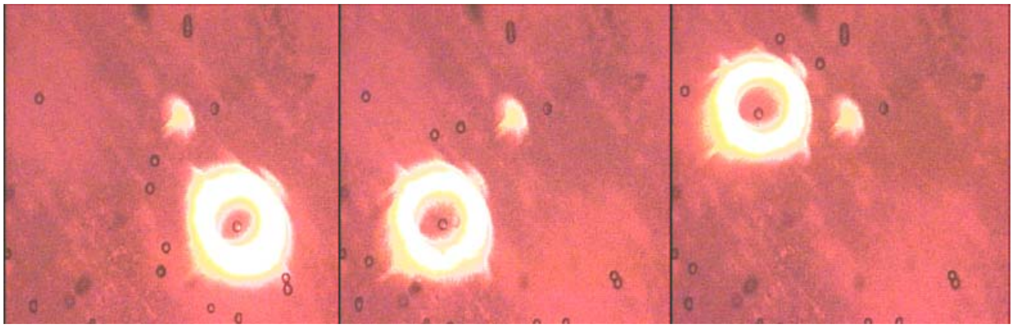

(d) (e) (f)

Fig.3. (a-c) Trapping of particles using a dynamic line cage. (d-f) Dynamic ring trap. The trap moves the particle in the center, while repelling particles outside the ring.

4. Conclusion

We have demonstrated the manipulation of micron-sized particles using optically-induced dielectrophoresis from a non-coherent light source. Various dynamic light patterns were successfully used as particle traps and manipulators, moving 25-µm latex spheres at approximately 40 µm/sec in a 0.1 mS/m buffer solution.

5. References

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