How Advanced Optical Tweezers Revolutionized Cell Manipulation

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A new review looks at devices called optical tweezers and how they are used to better uncover the natural secrets of human life at the single-cell level.

Optical tweezers (OTs), also known as optical traps, are highly focused laser beams that can be used to trap and manipulate microscopic objects with a noncontact force. Employed in a wide range of nano and micro-scale operations, OTs have become particularly useful in the manipulation of biological objects including human cells.

A new review published in EPJ Plus conveys the latest achievements in OTs over recent decades. The review is authored by researchers from the College of Information Science and Engineering, Northeastern University, Shenyang, China—Sheng Hu, Jun-yan Ye, Yong Zhao and Cheng-Liang Zhu.

“It is well-known that the cell is the basic unit of human life. If we can understand mutation, proliferation, and necrosis of cells, diseases inside the human body would be discovered and solved in the level of the cell,” Hu says. “Thus, optical tweezers, are a can be thought of as a pioneer used to confine these molecules so that more precise bio-measurement could capture the changes in one cell, including protein, mitochondria, and DNA.”

The authors begin by explaining the origins of OTs dating back to the work of James Clerk Maxwell and the fact that light, despite lacking mass, can possess momentum. Thus, the momentum of light could create a mechanical effect in matter. This concept would later be developed into the idea that small particles could be suspended by optical devices.

The authors point out that the advent of laser instruments—the coherent light with both high intensity and good monochromatic characteristics—led to the optical manipulation of such micro-particles, with the stable trapping of micro-particles achieved in 1986.

OTs have now developed to the stage at which they can be used to trap, sort, transport, and enrich various biological particles. For more complicated and delicate tasks, single optical beams are now bolstered by devices like acousto-optic modulators and electric vibrating mirrors.

The researchers add that OTs can now be used to accompany a new microscopy setup called “human bright eye” to manifest the microstructure composed of micro/nano-particles. This means OTs can act as a “human slender finger” holding onto these particles delicately while this faux human eye probes them.

The team details the advantages that OTs offer over similar techniques, such as atomic force microscopes (AFM), magnetic tweezers (MT), and acoustic tweezers (AT). These advantages include providing a finer force strength, their non-invasive nature, and the fact they are made up of multiple optical components.

This means optical manipulation and OTs specifically have found uses in fields as diverse as biology, pharmacology, and clinical research fields gripping nano and micro particles from molecules through to cells.

“Considering the potential ‘real world’ applications of OTs there is still a long way to go,” Hu concluded. “For example, the problem of radiation exposure to cells or proteins needs to be improved. Moreover, achieving stability of optical patterns to submicro-scale particles is still tough, reflecting a complicated optical adjustment. Although this can lead to confusion and even sometimes frustration, the intriguing biological presentations motivate us to facilitate the progress of the technique.”

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