To Capture Cells, MIT Researchers Developed a Tiny "Tractor Beam."

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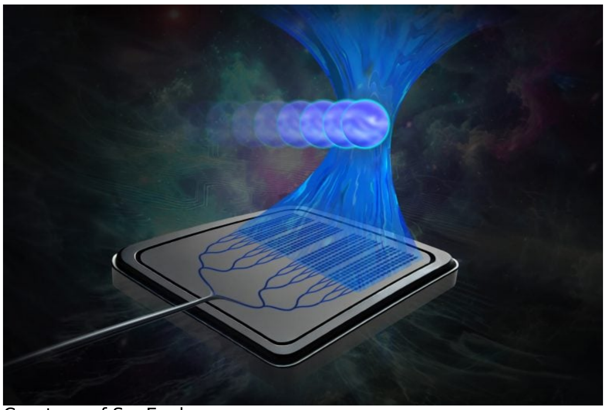

Courtesy of SynEvol
Credit: MIT

A tiny, chip-based "tractor beam," similar to the one that grabs the Millennium Falcon in the movie "Star Wars," has been created by MIT researchers. It may one day aid biologists and medical professionals in studying DNA, categorizing cells, and looking into the causes of illness.

The device, which is small enough to fit in your palm, manipulates particles millimeters away from the chip surface using a light beam emitted by a silicon-photonics chip. Cells can stay in a sterile environment since the light can pass through the glass cover slips that shield samples used in biological studies.

Chip-based optical tweezers could provide a more portable, mass-manufacturable, widely available, and high-throughput solution for optical manipulation in biological experiments. Traditional optical tweezers, which use light to trap and manipulate particles, typically require large microscope setups.

Other comparable integrated optical tweezers, however, are limited to capturing and working with cells that are either directly on the chip surface or extremely near to it. This limits compatibility with common biological studies by contaminating the chip and possibly stressing the cells.

In order to capture and tweeze cells more than a hundred times farther away from the chip surface, the MIT researchers have created a new modality for integrated optical tweezers using a technology known as an integrated optical phased array.

This discovery makes it possible to trap and tweeze cells at far greater distances than had been previously shown, which creates new opportunities for chip-based optical tweezers. Jelena Notaros, a member of the Research Laboratory of Electronics and the Robert J. Shillman Career Development Professor in Electrical Engineering and Computer Science (EECS), says it's thrilling to consider the various applications that this technology may permit.

A concentrated light beam is employed by optical traps and tweezers to collect and work with small particles. Microparticles will be drawn toward and captured by the beam's forces as they approach the tightly focused light in the center. Researchers can use noncontact forces to manage small objects by pulling the microparticles along with the light beam.

To collect and work with small particles, optical traps and tweezers use a concentrated light beam. Microparticles will be drawn toward the strongly focused light in the center by the forces applied by the beam, which will capture them. Researchers may manipulate microscopic objects using noncontact forces by guiding the light beam and pulling the microparticles along with it.

However, these earlier systems could only trap particles a few millimeters from the chip surface because chip-based optical tweezers could only emit light extremely close to the chip surface. Cells must be removed and placed on the chip's surface in order to handle biological specimens, which are normally kept in sterile conditions using glass cover slips that are around 150 microns thick.

But that results in contaminated chips. The chip must be discarded and the cells must be placed on a fresh chip each time an experiment is completed.

The MIT researchers created a silicon photonics chip that focuses a laser beam around five millimeters above its surface in order to get over these obstacles. By doing this, they may prevent contamination of the chip and the biological particles by capturing and manipulating them while they are still inside a sterile cover slip.

The researchers use a device known as an integrated optical phased array to do this. This technology uses semiconductor manufacturing techniques to create a number of microscale antennas on a chip. Researchers can mold and direct the light beam that the chip emits by electronically regulating the optical signal that each antenna emits.

The majority of earlier integrated optical phased arrays were not made to produce the narrowly focused beams required for optical tweezing, while being inspired by long-range applications such as lidar. The MIT team found that they could create a highly concentrated laser beam that can be utilized for optical trapping and tweezing millimeters from the chip's surface by designing distinct phase patterns for each antenna.

Prior to this, no one had developed optical tweezers based on silicon photonics that could capture microparticles over a millimeter-scale distance. "Compared to previous demonstrations, this is an improvement that is several orders of magnitude higher," Notaros says.

The researchers were able to control the concentrated beam over a range greater than a millimeter and with microscale precision by altering the wavelength of the optical signal that drives the chip.

The researchers first attempted to catch and control little polystyrene spheres in order to test their technology. After they were successful, they proceeded to use the Voldman group's cancer cells to trap and tweeze them.

"The process of applying silicon photonics to biophysics presented a number of unique challenges," Sneh continues.

For example, the researchers needed to figure out how to semiautomatically follow the motion of the sample particles, estimate the ideal trap strength to hold the particles in place, and efficiently postprocess data.

Ultimately, they were able to demonstrate the first single-beam optical tweezers cell tests.

Based on these findings, the group intends to improve the system so that the laser beam's focal height can be changed. In order to manage biological particles in more intricate ways, they also hope to adapt the device to various biological systems and simultaneously use several trap sites.
