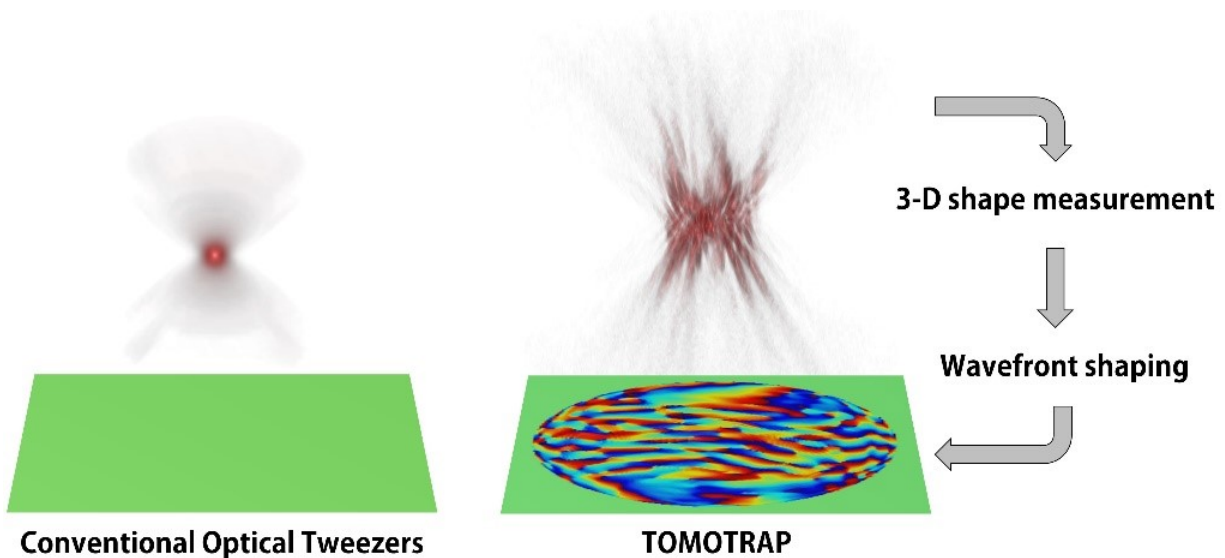


Controlling 3-D behavior of biological cells using laser holographic techniques

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A concept of optical manipulation techniques. Credit: KAIST

A research team led by Professor YongKeun Park of the Physics Department at KAIST has developed an optical manipulation technique that can freely control the position, orientation, and shape of microscopic samples having complex shapes. The study has been published online in *Nature Communications* on May 22.

Conventional optical manipulation techniques called "optical tweezers," have been used as an invaluable tool for exerting micro-scale force on

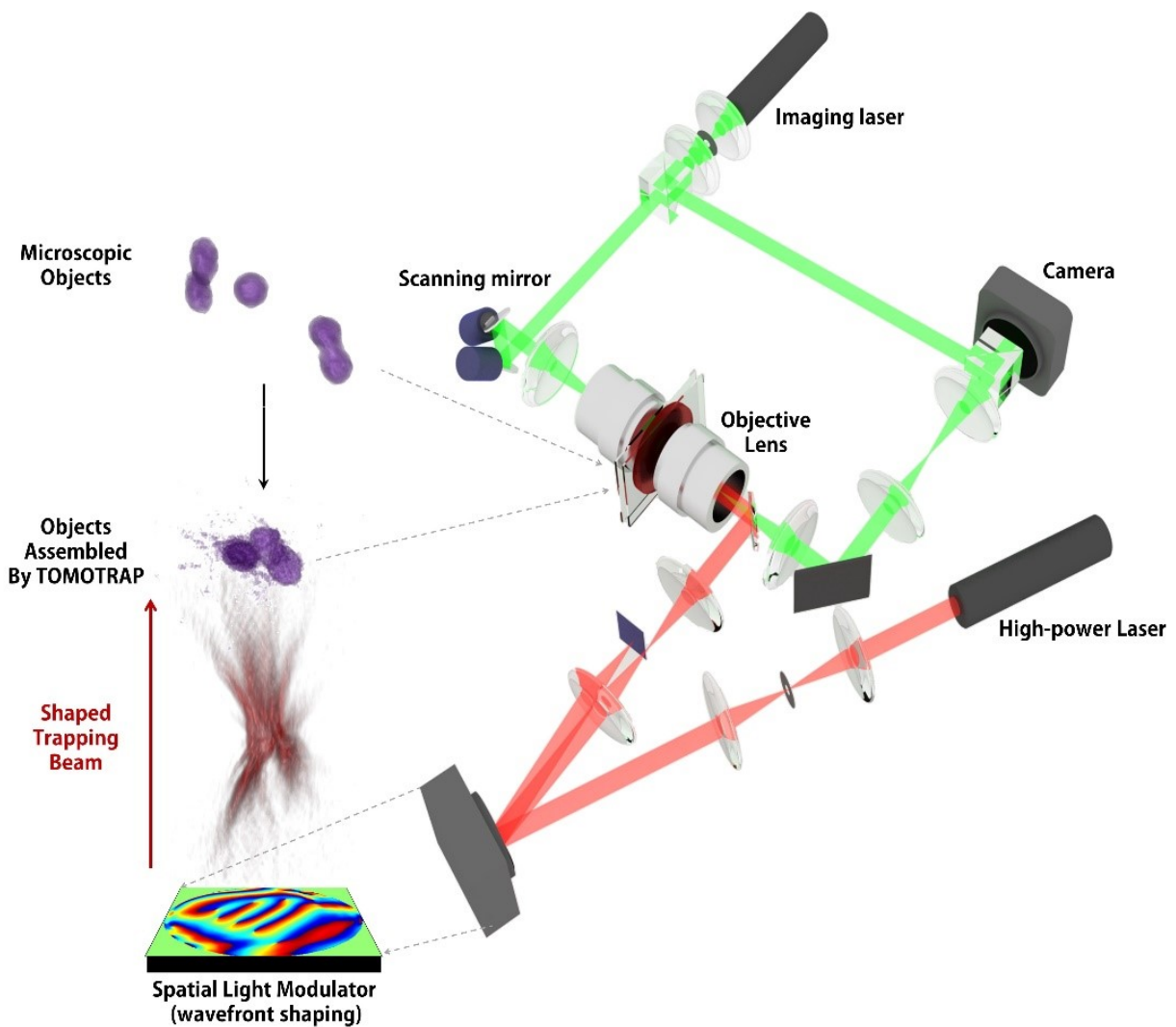
[microscopic particles](#) and manipulating three-dimensional (3-D) positions of [particles](#). Optical tweezers employ a tightly-focused laser whose beam diameter is smaller than one micrometer (1/100 of hair thickness), which can generate attractive force on neighboring microscopic particles moving toward the beam focus. Controlling the positions of the beam focus enabled researchers to hold the particles and move them freely to other locations so they coined the name "optical tweezers," and have been widely used in various fields of physical and biological studies.

So far, most experiments using optical tweezers have been conducted for trapping spherical particles because physical principles can easily predict optical forces and the responding motion of microspheres. For trapping objects having complicated shapes, however, conventional [optical tweezers](#) induce unstable motion of such particles, and controllable orientation of such objects is limited, which hinder controlling the 3-D motion of microscopic objects having complex shapes such as living [cells](#).

The research team has developed a new optical manipulation [technique](#) that can trap complex objects of arbitrary shapes. This technique first measures 3-D structures of an object in real time using a 3-D holographic microscope, which shares the same physical principle of X-Ray CT imaging. Based on the measured 3-D shape of the object, the researchers precisely calculates the shape of light that can stably control the object. When the shape of light is the same as the shape of the object, the energy of the object is minimized, which provides the stable trapping of the object having the complicated shape.

Moreover, by controlling the shape of light to have various positions, directions, and shapes of objects, it is possible to freely control the 3-D motion of the object and make the [object](#) have a desired shape. This process resembles the generation of a mold for casting a statue having

desired shape so the researchers coined the name of the present technique "tomographic mold for optical trapping (TOMOTRAP)." The team succeeded in trapping individual human red blood cells stably, rotating them with desired orientations, folding them in an L-shape, and assembling two [red blood cells](#) together to form a new structure. In addition, colon cancer cells having a complex structure could be stably trapped and rotated at desired orientations. All of which have been difficult to be realized by the conventional optical techniques.



The experimental setup. Credit: KAIST

Professor Park said, "Our technique has the advantage of controlling the 3-D motion of complex shaped objects without knowing prior information about their shape and optical characteristics, and can be applied in various fields including physics, optics, nanotechnology, and medical science."

Dr. Kyoo Hyun Kim, the lead author of this paper, noted that this technique can induce controlled deformation of biological cells with desired shapes. "This approach can be also applied to real-time monitoring of surgical prognosis of cellular-level surgeries for capturing and deforming cells as well as subcellular organelles," added Kim.

More information: Kyoo Hyun Kim et al, Tomographic active optical trapping of arbitrarily shaped objects by exploiting 3D refractive index maps, *Nature Communications* (2017). [DOI: 10.1038/ncomms15340](https://doi.org/10.1038/ncomms15340)

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