1-1-11. Optical Tweezers

Overview

Optical tweezers have been important and powerful tools for trapping and manipulation of micro/nano-objects. Optical tweezers have continuously been advanced on demands in physical, chemical, and biomedical applications. In the traditional optical tweezers, a laser beam (preferably with a Gaussian mode) is introduced into an optical microscope and focused via an objective lens with a high value of numerical aperture (N. A.) into a solution containing particles as a trapping target. In Fig. 1, optical tweezer apparatus is schematically illustrated.

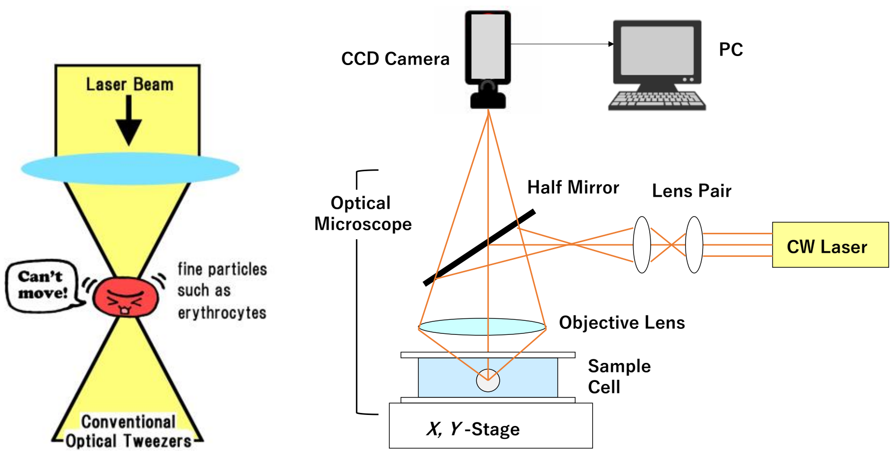

Figure 1. Concept and apparatus setup of an optical tweezer.

Current Status and Frontiers

1. Physics

One of the most hot topics in physics is the quantum information processing. In the quantum computing, atm (nuclear spin) acts as a qubit. The spin serves as a long-lived and coherent two-level system. To keep the coherence, each atom should be isolated and put in the same environment. Optical tweezers are used to trap individual neutral atoms in specific locations, forming a lattice or array of qubits. This is called “optical tweezer array”. These trapped atoms can be manipulated using additional laser beams to perform quantum gates and create entangled states. Optical tweezers provide a flexible and precise method for controlling neutral-atom qubits, making them a valuable tool in neutral-atom quantum computing.

2. Biology and life science

The origin of symmetry breaking in living organisms is crucially important and still remains unclear, although numerous researches have been conducted. Recently, a research group in RIKEN have discovered how tiny hairs in embryos (cilia at the ventral node of mouse embryos) detect flowing fluid, which ultimately leads to the left and right sides of the embryo developing differences. Application of mechanical stimuli to immotile cilia by optical tweezers induced calcium ion transients and degradation of Dand5 messenger RNA (mRNA) in the targeted cells. That is the origin of symmetry breaking in living organisms.

3. Environmental science and chemistry

A research group in OIST has revealed the presence of small microplastics in the ocean surrounding Okinawa, which is very clear and beautiful. They sampled sea water of ocean surrounding Okinawa. For the sample, they analyzed 282 particles in the sea water one-by-one using a combination of optical tweezers technique and the micro-Raman spectroscopy. They revealed the sea water contained organic materials, trace metals, and different plastics like polyethylene or polystyrene. 17 % of total particles was occupied by microplastics.

For photochemistry, several research groups demonstrated crystallization, amyloid fibrils formation, and ionic exchange in perovskite. Tsuboi et al. developed novel optical tweezers using surface plasmon and Mie resonance. They applied these tools to control photochemical initial process such as excimer formation and FRET.

References

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Future Perspectives and Directions

Molecular manipulation, Industrial application

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