L.4: Optical Twisters-Driven Multi-Layered Microrotors

The use of structured light-driven optical traps for controlled rotation and orientation of micro particles has received considerable interest for applications in micro fluidics, cell biology and medicine. One of the approaches used for this purpose is to transfer the intrinsic orbital angular momentum of a Laguerre-Gaussian (LG) beam to the optically trapped particle. Recently we demonstrated an implementation of this approach for controlled rotation of red blood cells. Although simple in implantation the approach lacks the control over the size scale or the geometry of the micro-structure to be driven by light. The use of propagating multi-arm light patterns generated by the interference of specially configured beams like LG beams or Bessel beams with a Gaussian beam to drive microrotors avoids these problems. However, these approaches are not amenable for the implementation of multiple microrotors having tunable sense of rotation as may be desired for some applications. We recently demonstrated the generation of optical traps within individually tunable three dimensional (3D) helical field patterns by the designed superposition of phase engineered multiple plane waves using a programmable spatial light modulator (SLM)-assisted approach. Compared to the case where LG or Bessel beams are used, the present approach offers flexibility in fine-tuning the intensity levels and shape of individual arm of the rotating light pattern. We further demonstrated the use of these 3D optical twister traps to drive particles stacked in a 3D helical multi-layered arrangement as controlled multi-armed microrotors as well as their parallel actuation in various array shapes.

The generated spiral arm structure by multiple plane wave interference could be tailored by varying the values of amplitude, phase and the radius of curvature of the centrally launched perturbing non-singular beam or by the choice of number of plane waves with independently controllable offset phase or by controlling the amplitude ratio among the set of interfering plane waves as well as by adjusting their position in the Fourier plane. In this respect the trapping of microparticles within the interference patterns of specially configured beams offers greater flexibility as optically-driven microrotors. Based on these longitudinally gyrating three dimensional interference patterns, we have been able to realize tunable multi-layered microrotors by trapping multiple layers of 2 μm diameter silica spheres (Fig.L.4.1).

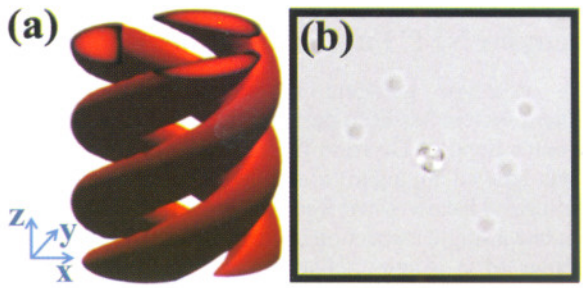

Fig.L.4.1: (a) Computed 3D intensity profile of intertwined 3D twister interference pattern by phase engineered 18(side beams) +1(central beam) beam interference (b) 3D helically stacking of 2μ Si particles in a rotor trap. The second layer of particles is azimuthally shifted from the first layer (appearing dark) and can be distinguished from their bright appearance.

Further by superposing appropriate grating terms into the computer generated holograms over the 18+1 beam interference patterns to control the positions of intended rotary trap patterns, parallel actuation of multiple microrotors could also be achieved (Fig. L.4.2). Such assemblies can act like controlled micro-stirrers or mixers and when arranged in a dual row like manner with opposite sense of rotation, these may function as tunable micro-pumps.

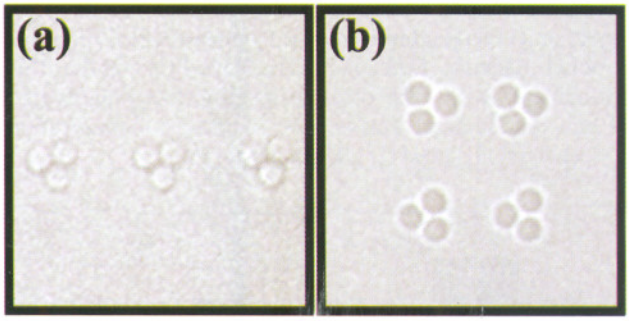

Fig.L.4.2. (a) One row of three triple armed microrotors. (b) Triple-armed microrotors in two rows.

The helical 3D stacking of micro-particles to form multi layered micro rotor and in-plane parallel actuation of multiple microrotors as we demonstrated, have potential applications in areas like bio-micromotors attached to various bio-elements like DNA, reconfigurable micro-pumps, tunable particle sorting micromachines etc.

Reported by:
R. Dasgupta (raktim@rrcat.gov.in),
S. Ahlawat and P. K. Gupta