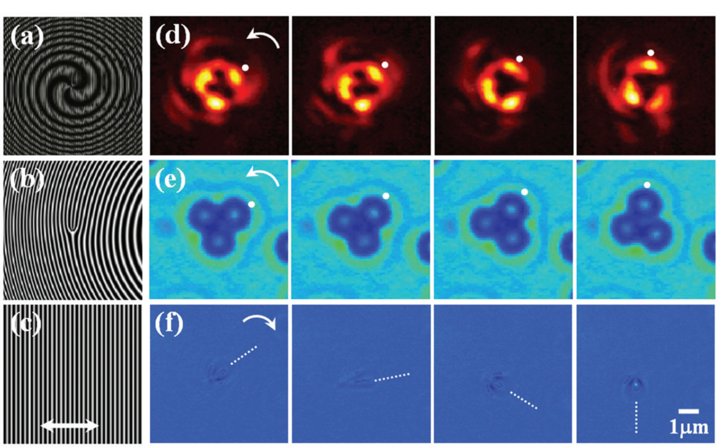
OPTICAL TWEEZERS

Rotating Beads and Bacteria with **Moiré-based Optical Tweezers**

Since Ashkin's pioneering work,[1] optical trapping and manipulation have been of great interest to the optical community. Researchers have proposed many techniques for optically rotating trapped particles,[2,3] but most relied on either mechanical instruments or phase-sensitive interference, which is susceptible to ambient perturbation. Recently, we demonstrated an approach for generating rotating intensity blades using the moiré technique.[4] Our propelling beams can be generated with variable speed and direction of rotation without requiring mechanical movement or optical interference. Furthermore, they can achieve dynamic control of trapped micro-particles and bacteria.[5]

To create optical propelling beams from moiré fringes, we overlapped a simple straight-line grating (by interfering two plane waves) and a spiral fork-type grating (by interfering a plane wave and a diverging vortex beam), for the example of topological charges m=3. After spatial filtering, the moiré patterns were successfully retrieved. The number of intensity blades was determined by the topological charge of the vortex.

When one moves the simple grating along the grating-vector direction, the moiré patterns can rotate clockwise or counterclockwise, depending on the direction of the grating's movement and/or the sign of the vortex charge. The rotation speed of the moiré pattern is proportional to that of the grating motion. Even after tight focusing, the fine features of a three-blade pattern are preserved. With such well-resolved multi-blade intensity structures, we achieved in-plane stable optical trapping and controlled rotation of *E. coli* bacteria as well as polystyrene micro-beads.



(a) Moiré pattern used to generate three-blade rotating beams by overlapping (b) a curved fork-type vortex grating (m=3) with (c) a straight-line grating. (d) Experimentally generated three-blade propelling beams after focusing the moiré pattern shown in (a). (e) Optical trapping and rotation of 2 µm polystyrene beads. (f) Optical rotation of an *E. coli* bacterium. In (f), rotation direction is reversed. White dashed lines indicate orientation of the bacterium; white arrows shows rotation direction.

We used a sample of 2-µm polystyrene beads suspended in water. As expected, a rotating beam with a particular number of blades would trap and rotate the corresponding number of particles by optical gradient forces. By reversing the rotating direction of the propelling beam, the rotation direction of the particles was also reversed. In principle, our technique can be implemented with incoherent white-light sources, as we demonstrated multi-blade white-light propelling beams.[5] OPN

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