

Trapping Force in Near-field Laser Tweezers

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Abstract— Recently near-field trapping using a focused evanescent field generated by a high numerical aperture (NA) total internal reflection (TIR) objective with an annular beam has been proposed and demonstrated to be advantageous over the far-field trapping due to the significantly reduced focal volume, which can substantially suppress the background and heating effect [1,2]. In the mean time, rotation mechanisms, which are of great importance in terms of achieving a complete manipulation of the trapped micro-objects, can be potentially introduced by dynamically controlling the phase, amplitude or even polarization states of the incident beam, whereas in other near-field trapping scheme, such as using a metallic tip, it is rather challenging [3]. To this end Laguerre-Gaussian (LG) beams, which have been commonly used in far-field laser trapping for rotation due to carrying orbital angular momentum, was combined with the focused evanescent illumination. It was revealed by near-field optical microscopy that an anomalous deformation occurs to the focal intensity distribution of a focused evanescent LG beam owing to the phase dislocation originated from the interplay of the phase shift induced by the TIR and the spiral phase front of the LG beam [4]. Under such a circumstance, a complete transverse force mapping is essential to reveal the interaction between the laser focus and the micro-objects since the symmetry of the field is broken. In this paper, theoretical investigations on the two-dimensional transverse trapping efficiency of a dielectric micro-particle under the illumination of a focused evanescent LG beam are presented. The complete 2D trapping force mapping is implemented by using the Maxwell stress tensor approach combined with the vectorial diffraction theory [5]. It is revealed that the severe focal field deformation associated with a focused evanescent LG beam causes significant impact on the transverse trapping performance of the micro-particle. A strong tangential force component is observed in the transverse efficiency mapping, which potentially induces the rotational motion to the particle within a small trapping volume in the optical near-field.

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