Displacement trajectory of nanoparticles illuminated by pulsed photonic jet and photonic hook

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Abstract: We present the displacement trajectory of a gold nanoparticle under photonic nano-jet and photonic hook fields generated with an ultrashort pulsed beam. We compared the optical forces exerted on the nanoparticle under pulsed and CW illumination and calculated its displacement. We observed peculiar nanoparticle trajectories when placed in different initial positions, under pulsed light. To understand the effect, we analyzed the gradient and scattering forces. Our work stimulates the development of experimental methods for opto-mechanical manipulation.

The trapping and manipulation of particles by optical tools have been widely used in biological research and implemented in medicine [1], yet nanoscale objects cannot be manipulated by such tools due to the diffraction limit of light [2]. Therefore, achieving manipulation on the nanoscale requires auxiliary structures that generate a tightly confined electric field. Photonic nano-jets are high intensity, narrow light beams generated by dielectric structures that are subjected to illumination by a plane wave [3]. When the symmetry is broken, the generated structured light becomes curved, which is known as a photonic hook effect [4]. In this research, we report the displacement trajectory of gold nanoparticles under photonic nano-jet and hook fields generated with an ultrashort pulsed beam. The studied system is composed of a micro-cylinder and metallic mask that partially blocks the incident light and creates an asymmetric illumination [5]. We simulated the electric fields and calculated the optical forces exerted on the nanoparticle. We compared between continuous wave and pulsed illumination, and found that the forces exerted on the gold nanoparticle generated via pulsed illumination are five orders of magnitude higher and are significant enough to move the nanoparticle. We observed peculiar nanoparticle trajectories when placed in different initial positions, and found that the trajectory is not affected by input intensity. To better understand our results, we analyzed the gradient and scattering forces exerted on the nanoparticle by the photonic nano-jet and hook. Our results stimulate the development of experimental methods for the opto-mechanical manipulation of nanoparticles. Opto-mechanical manipulation opens a venue for future fundamental investigations and a range of practical applications, where accurate control over the mechanical motion of small objects is required.

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