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Dynamics of optically levitated microparticles in vacuum placed in 2D and 3D optical potentials possessing orbital angular momentum

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Abstract: We demonstrate the transfer of orbital angular momentum to optically levitated microparticles in vacuum [1]. We prepare two-dimensional and three-dimensional optical potentials. In the former case the microparticle is placed within a Laguerre-Gaussian beam and orbits the annular beam profile with increasing angular velocity as the air drag coefficient is reduced. We explore the particle dynamics as a function of the topological charge of the levitating beam. Our results reveal that there is a fundamental limit to the orbital angular momentum that may be transferred to a trapped particle, dependent upon the beam parameters and inertial forces present. This effect was predicted theoretically [2] and can be understood considering the underlying dynamics arising from the link between the magnitude of the azimuthal index and the beam radius [3].

Whilst a Laguerre-Gaussian beam scales in size with azimuthal index ℓ, recently we have created a "perfect" vortex beam whose radial intensity profile and radius are both independent of topological charge [4, 5]. As the Fourier transform of a perfect vortex yields a Bessel beam. Imaging a perfect vortex, with its subsequent propagation thus realises a complex three dimensional optical field. In this scenario we load individual silica microparticles into this field and observe their trajectories. The optical gradient and scattering forces interplay with the inertial and gravitational forces acting on the trapped particle, including the rotational degrees of freedom. As a result the trapped microparticle exhibits a complex three dimensional motion that includes a periodic orbital motion between the Bessel and the perfect vortex beam. We are able to determine the three dimensional optical potential *in situ* by tracking the particle. This first demonstration of trapping microparticles within a complex three dimensional optical potential in vacuum opens up new possibilities for fundamental studies of many-body dynamics, mesoscopic entanglement [6, 7], and optical binding [8, 9].

OCIS codes: Levitated optomechanics, Orbital angular momentum, Laguerre-Gaussian beam, Perfect vortex

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