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PARTICLE MANIPULATION USING EVANESCENT LIGHT FIELDS OF OPTICAL NANOFIBRES

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Abstract

We discuss microparticle manipulation in the evanescent field of an optical nanofibre. Due to the nonparaxial nature of the tightly confined field, observation of the transverse spin of light becomes possible. We also note that inhomogeneous particles, such as gold-silica Janus particles, can be trapped using the evanescent field, with the gold cap acting as an optical sail. Some of the subtleties of the nature of the evanescent light field will be explored.

1 Particle Manipulation using Optical Nanofibres

In recent years, optical nanofibres are being used as alternatives to optical tweezers for micro- and nanoparticle trapping, manipulation, and sorting [1-4]. The intense evanescent field with a steep field gradient provides a strong trapping force consisting of gradient and scattering force components. Using counterpropagating beams in the nanofibre can localise the particles at specific positions allowing us to observe coupling of the spin component of light to orbital motion of the particle [5]. Recently, methods to control the polarisation of light in the evanescent field [6-8] have dramatically improved the functionality of optical nanofibres as particle trapping devices, allowing us to observe the transverse spin angular momentum of light and to exploit inhomogeneities in the particle's composition to emphasise some of the features of the light field.

1.1 Observation of the transverse spin of light using anisotropic particles in an evanescent field

In contrast to paraxial light, tightly confined light carries an appreciable amount of transverse spin angular momentum, $\mathbf{S}_{\perp}$. We have detected $\mathbf{S}_{\perp}$ in the evanescent field near the waist of an optical nanofibre by observing the rotation of an anisotropic microparticle held near the fibre and rotated using an optical tweezers, see Figure 1. By setting the optical tweezer's driving spin angular momentum to be parallel or antiparallel with respect to the transverse spin near the nanofibre, we can change the rate of the particle's rotation compared to the case where there is no light propagating in the fibre [9].

1.2 Janus particle manipulation in an evanescent field

Janus particles are composite particles that have gained interest in the research community recently, primarily in relation to biomedical applications. Such particles can act as micro- or nanoactuators, carriers, or imaging agents. One major challenge is the manipulation of Janus particles as they can be difficult to trap in standard optical tweezers. We demonstrate that the optical forces in the evanescent field of an optical nanofibre can be used to efficiently manipulate Janus particles consisting of silica microspheres half-coated with gold. We find that the Janus particles exhibit stronger transverse localisation and faster propulsion compared to silica particles of comparable size [10].

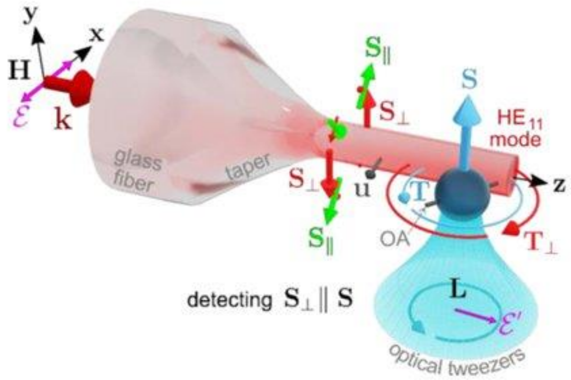

Figure 1 *Schematic of the experiment for a demonstration of the transverse spin of light. An anisotropic particle is trapped using an optical tweezers and placed in the evanescent field of an optical nanofibre. An optical torque* $\mathbf{T}_{\perp}$ *is produced via the transverse spin of light* $\mathbf{S}_{\perp}$ *and this contributes to the total torque* $\mathbf{T}$ *on the particle [9].*

2 Conclusion

We have presented several optical manipulation examples using nanofibre waveguides to control the motion of microparticles in the evanescent light field. The highly confined electromagnetic field allows us to demonstrate effects that are not easily observed using paraxial light fields, such as the transverse spin of light. By careful choice of the particle, we have been able to observe spin-orbit coupling, whereby the polarisation of the light influences the orbital motion of the particle around the optical nanofibre, and the transverse spin angular momentum of light. In future, we will focus our work on nonspherical particles.

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