Evanescent wave optical trapping and manipulation of particles and nanostructures

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Abstract: Optical trapping is a powerful technique for the controlled manipulation of particles with sizes in the micron, sub-micron and nanometre range[1]. Conventional optical tweezers using a single, strongly-focused laser beam to confine particles within the focal volume of $\approx 1\mu m^3$. Optical binding describes the self-organisation of microparticles and nanostructures in an optical field that occurs over long distances and extended areas arising from the multiple scattering of light.

Here we present experimental schemes for the control of optically bounds structures in evanescent optical fields. The first relies on total internal reflection at an interface, where the evanescent field penetrates a short distance (comparable to, or less than the optical wavelength) above the interface. We show that this geometry, shown in Figure 1(a), gives rise to one- and two-dimensional optically ordered structures of microparticles and also of nanostructures immersed in the field, shown in Figure 1(b) – (d), and quantify the binding forces and structure geometries via video microscopy[2,3].

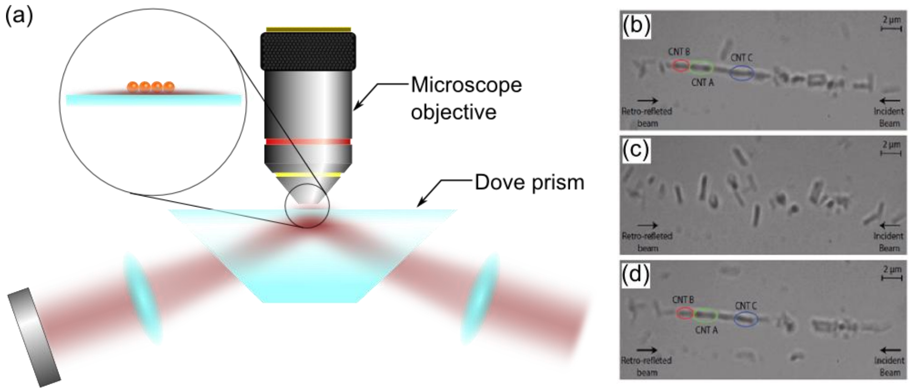

Figure 1: Optical binding of carbon nanostructures. (a) Set-up of the optical binding experiment; (b) Optically bound chain of carbon nanotube bundles; (c) When the laser beam is turned off the chain disintegrates; (d) Laser beam on, chain re-forms

The second geometry uses optical waveguides of sub-optical wavelength dimension. For our experiments these are optical fibres that are adiabatically tapered to $<1\mu m$ in diameter. Such a waveguide supports the fundamental mode only, but a large fraction of the power propagates in an evanescent field that can penetrate a significant distance in the surroundings. We show here how this field can be used for optical binding of particles to the nanofibre and long-range transport along the length of the tapered region[4].

References

1. O. M. Maragò, P. H. Jones, P. G. Gucciardi, G. Volpe & A. C. Ferrari. '*Optical trapping and manipulation of nanostructures*', Nature Nanotechnology **8** 807-819 (2013)
2. M. Sergides, S. E. Skelton, E. Karczewska, K. Thorneycroft, O. M. Maragó & P. H. Jones. '*Optically bound particle structures in evanescent wave traps*', Proc. SPIE **8458**, Optical Trapping and Optical Micromanipulation IX, 84583C, doi: 10.1117/12.929612 (2012)
3. S. H. Simpson, P. H. Jones, O. M. Maragò, S. Hanna & M. J. Miles. '*Optical binding of nanowires in counter-propagating beams*', Proc SPIE **8810** Optical Trapping and Optical Micromanipulation X, 881026, doi: 10.1117/12.2024466 (2013)
4. S. E. Skelton, M. Sergides, R. Patel, E. Karczewska, O. M. Maragó & P. H. Jones. '*Evanescent wave optical trapping and transport of micro- and nanoparticles on tapered optical fibers*', Journal of Quantitative Spectroscopy and Radiative Transfer **113** 2512-2520 (2012)