Optical trap arrays in few-mode tapered glass capillaries

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Photonic waveguides are key photonic components as they not only guide light but also provide different means to act on the guided light's properties (polarization, wavelength, angular momentum…) and to control its interaction with other optical systems such as optical resonators and light emitters/absorbers/scatterers. While optical nanofibers and integrated nanobeam waveguides enable near-field interactions with their environment [1], hollow-core waveguides provide a unique platform that enables the guided light to interact with liquid- or gas-phase materials with an increased efficiency [2]. Especially, liquid-core photonic waveguides with a wavelength-scale diameter can enhance light-matter interactions between guided light and nanomaterials dispersed in a liquid medium. In a recent work, tapered glass capillaries with few-micrometer-large diameters have been used to optically transport fluorescent nanodiamonds and sort them according to their size [3].

In this work, we investigate possible techniques to optical trap and manipulate nanoparticles in a water-filled tapered glass capillary with a sub-micrometer-scale outer radius. On the one hand, counter-propagating guided laser beams can form an optical trap array with a period of half the effective wavelength. On the other hand, co-propagating modes with different propagation constants can form optical trap arrays with longer periods, typically one order of magnitude longer than the wavelength. Based on numerical results, we analyze what guided modes should be excited to form optical trap arrays in tapered glass capillaries. For each case, the optical force acting on the trapped nanoparticles is evaluated. Our results may explain experimental observation of the non-uniform transport of fluorescent nanodiamonds inside narrow glass capillaries.

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