Long-distance axial trapping with focused annular laser beams

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Focusing an annular laser beam can improve the axial trapping efficiency due to the reduction of the scattering force, which enables the use of a lower numerical aperture (NA) objective lens with a long working distance to trap particles in deeper aqueous medium. In this paper, we investigate theoretically the optical trapping efficiency on dielectric particles and make comparison of the axial and lateral trapping efficiencies for different widths of the annular beams by using vectorial diffraction theory. We present an axicon-to-axicon scheme for producing parallel annular beams with the advantages of higher efficiency compared with the obstructed beam approach. The validity of the scheme is verified by the observation of a stable trapping of silica microspheres with relatively low NA microscope objective lenses (NA=0.6 and 0.45), and the maximal axial trapping depth can reach up to 13mm. Due to the long distance imaging capability, the axicon-pair-based optical tweezers could also be a useful tool in various biological researches, for example, examining specimens in vitro through thick glass walls, where the objective lens must be protected against environmental hazards such as heat, vapors, and volatile chemicals by a thick coverslip.

Figure 1. Experimental layout of the optical trapping system. The inset gives the annular beam shape captured on Mirror 4.