Curved Laser Traps for Optical Manipulation of micro- and nanoparticles

Mercedes Angulo
José A. Rodrigo and Tatiana Alieva

Universidad Complutense de Madrid, Facultad de Ciencias Físicas, Madrid, Spain

merceang@ucm.es

Optical tweezers, which use strongly focused point-like laser beams to manipulate small particles, have revolutionized our understanding of the microworld, providing techniques for cell and single-molecule studies, for microfabrication, and more. However, most efforts have focused on manipulating individual micro-objects generally ignoring the problem of optical transportation of particles en masse of both micro- and nanoparticles.

Using a totally different approach, we have developed an optical manipulation tool that allows mass light-driven transport of metallic and dielectric micro- and nanoparticles [1-2]. This freestyle optical trap [2] is created with a strongly focused laser beam in the form of an arbitrary 2D or 3D light curve, defining the particle trajectory. It exploits the optical forces arising from the beam's intensity and phase gradients for particle confinement and propulsion along the required trajectory. The developed non-iterative trap design technique allows for fast automatic reconfiguration of particle trajectory and speed—similar to robotic motion planning—to avoid contact with, or to impact on, objects in the host environment in the 2D [1] and 3D [3] cases.

We have demonstrated these functionalities experimentally on metallic plasmonic nanoparticles [1], even by using a resonant laser wavelength to provide both optical transport and heating of the particles simultaneously—a capability of special interest for targeted drug delivery, micro-scale photothermal therapy and nanolithography. This strategy is extendable to 3D trajectories as our recent results confirm [3]. Moreover, the application of these curved laser traps for opto-electric printing of plasmonic nanoparitcles has been also exploited [4]. We envision that this new laser shaping technology will expand horizons in optical manipulation, light–material processing, micro/nano-fabrication and other applications yet to be explored.

References

[1] J.A. Rodrigo and T. Alieva, Sci. Rep., 6 (2016) 33729
[2] J.A. Rodrigo and T. Alieva, Optica, 2 (2015) 812
[3] J.A. Rodrigo, M. Angulo and T. Alieva, Opt. Express, Submitted (2018)
[4] J.A. Rodrigo, Sci. Rep., 7 (2017) 46506

Figures

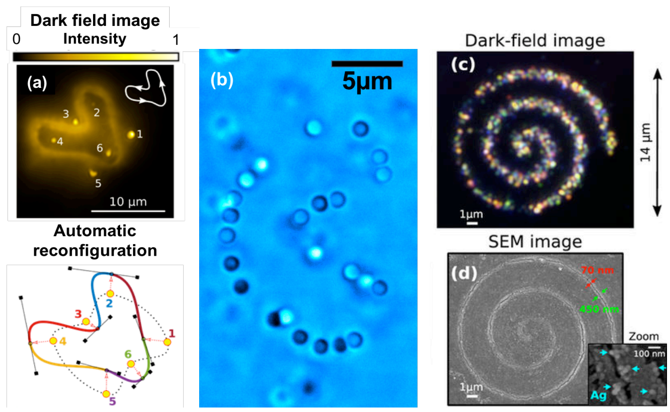

Figure 1: (a) Plasmonic nanoparticles, NPs, (100-nm-diameter gold spheres) are optically transported along reconfigurable 2D trajectories (time lapse image, see video online), following robotic motion planning based on Bézier paths. (b) Silica micro-particles (1000-nm-diameter) transported along reconfigurable and speed controlled 3D trajectory. Different particle appearance in the photogram indicates their axial position.
(c) Laser printing of silver NPs (40 nm) deposited on a transparent ITO electrode with freestyle trap. The color dark-filed image shows the light emitted by the silver NP assemblies created along an Archimedean spiral circuit, whose SEM image is displayed in (d). Zoom inset in (d) shows several subwavelength NP assemblies (≤150 nm).