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PHOTONICS - EUROPHOTONICS MASTER COURSE

MASTER THESIS PROPOSAL

Course 2014 –2015

**Laboratory : Conical Refraction Laboratory, Optics Group, UAB.
City, Country: Bellaterra (Spain).**

Title of the master thesis: Improving photophoretic optical trapping with conical refraction.

Name and affiliation of the tutors of the master thesis: Jordi Mompart and Alejandro Turpin

Institution: Universitat Autònoma de Barcelona.

Mail address: Optics Group, Department of Physics, Edifici Cc, Campus UAB.

Email address: alejandro.turpin@uab.cat

Phone number: +34 93 581 1652

Summary of the subject (maximum 1 page):

Since the late 70's of the last century, several different optical techniques have been developed to manipulate, i.e., to trap and transport, individual atoms/molecules and microparticles such as cells. To manipulate these microparticles, tightly focused beams are typically used that pass through the particles as if they were hang by invisible tweezers, known as optical tweezers. Although being a very flexible technique and broadly used nowadays, optical tweezers have the drawback that they can only be used to manipulate relatively small particles (on the order of a micron or less).

In the last years an alternative to optical tweezers that allows for the manipulation of macro-particles has started to be investigated. This alternative is based on the photophoretic force, an optical force with a thermodynamic origin that appears in absorbing particles surrounded by a medium, usually a gas. In photophoresis, when light is sent upon a particle, the latter one absorbs light's energy and heat propagates along its surface. The region of the gas in contact with the hottest region of the particle has the highest heat transfer from the particle to the gas which increases the kinetic energy of the surrounding gaseous particles. As a consequence, the surrounding medium interchanges linear momentum with the particle, especially around the hottest regions of the particle. Since the most usual situation is where light illuminates the particle only from one side, the overall result will be a movement of the particle away from the light source. Now, let's imagine that we are able to symmetrically shine the particle, so that it receives the same amount of light from all directions. In this case, the particle will also receive the same amount of momentum from the gas from all directions and it will remain stable at its position, i.e., the particle will be trapped.

It is not easy to imagine a single light beam being able of surrounding a particle symmetrically. It is necessary that the beam opens and closes itself, so that a region of space is less intense than any other neighboring region. Light beams with this behavior do exist and they are known as optical bottles [1]. Nevertheless, with such a beam there is still the open question of how the particle can enter into the optical bottle if it is refused by light? At the Optics Group from the Department of Physics of the Universitat Autònoma de Barcelona, we make use of the phenomenon of conical refraction in biaxial crystals to generate the most perfect and easiest optical bottle beams known up to now [2]. This phenomenon has the key to overcome the commented problem. When a light beam passes through a biaxial crystal, it is transformed into a macroscopic optical bottle, whose cross-section forms a pair of concentric bright rings. The most relevant signature of these rings is its polarization distribution, which allows opening and closing the bottle by just using a couple of wave retarders. This feature has been used by us to load the optical bottle with particles with diameters larger than the thickness of human hair, confine them the desired time and unload them at wish, efficiently [2].

In this master thesis it will be studied both experimentally and theoretically how to improve the trapping efficiency of absorbing particles in a photophoretic conical refraction trap. It will be analyzed the performance and statistics of the trap and implement novel configurations to increase the flexibility of the trap and allow for optical transport of the trapped particles.

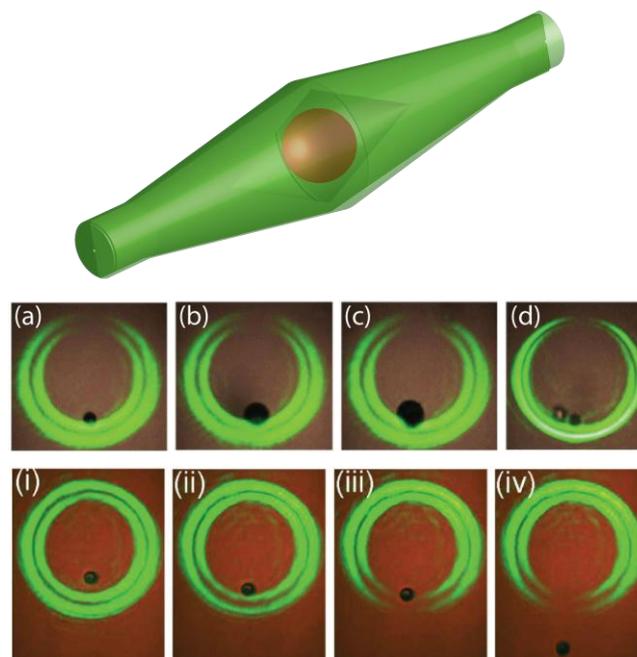


Figure: *Top part: an absorbing particle is confined in the optical vault generated by means of conical refraction. Bottom part: loading/unloading of particles into/from the trap.*

[1] J. Arlt and M. J. Padgett, "Generation of a beam with a dark focus surrounded by regions of higher intensity: the optical bottle beam," *Opt. Lett.* **25**, 191-193 (2000).

[2] A. Turpin, V. Shvedov, C. Hnatovsky, Yu. V. Loiko, J. Mompart, and W. Krolikowski, "Optical vault: A reconfigurable bottle beam based on conical refraction of light," *Opt. Express* **21**, 26335-26340 (2013).

Keywords : optical trapping, conical refraction, crystal optics.