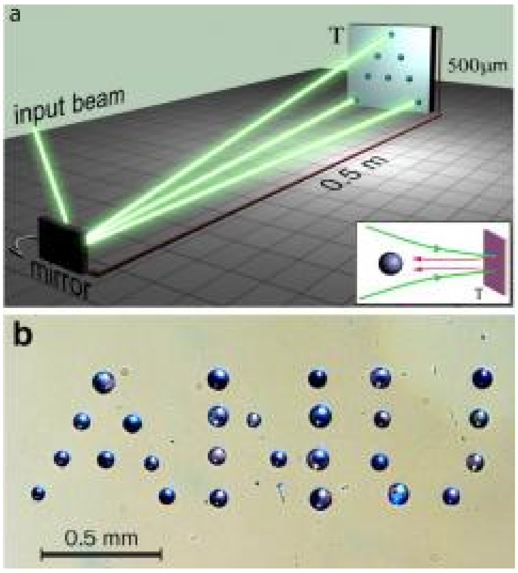
Scientists move objects across meter-scale distances using only light (w/ Video)

30 September 2010, By Lisa Zyga



(A) The set-up for transporting particles using optical vortex pipelines. (B) Microspheres form the abbreviation for the Australian National University, having been remotely deposited over a distance of 0.5 meters with a positioning accuracy of 10 micrometers. The microspheres' diameters vary from 60 to 100 micrometers. Image credit: Vladlen G. Shvedov, et al. ©2010 The American Physical Society.

(PhysOrg.com) -- For more than 40 years, scientists have been using the radiation pressure of light to move and manipulate small objects in space. But until now, the movements have always been restricted to very small scales, typically across distances of a few hundred micrometers, and mostly in liquids. In a new study, scientists have demonstrated a technique that achieves giant optical manipulation in air using a new kind of optical trap that can move 100-micrometer-sized objects across meter-scale distances with an accuracy of about 10 micrometers.

The researchers, Vladlen Shvedov from the Australian National University in Canberra, Australia, and Taurida National University in Simferopol, Ukraine, and coauthors, have published their study in a recent issue of Physical Review Letters.

As the scientists explain, moving objects with light can be done using the photophoresis effect in air and other gases. When a particle is heated nonuniformly by light, the surrounding gas molecules bounce off the particle's surface with different velocities, creating a force on the particle that pushes it in the direction from the higher illumination to the lower illumination.

In the new study, the scientists have modified the usual optical trapping system by incorporating optical vortex beams with a doughnut-like cross-section to create an optical pipeline in which the bright ring of light intensity acts as a repelling "pipe wall" that traps light-absorbing particles in the dark center of the beam. The axial component of the vortex beam's thermal force pushes particles along the pipeline, and a movable mirror can control the direction of the beam for aiming particles at targets located up to a meter away.

The researchers demonstrated the long-distance optical manipulation using two types of particles: agglomerates of carbon nanoparticles with diameters of 100 nanometers to 100 micrometers and carbon-coated hollow glass microspheres with diameters of 50-100 micrometers. In both cases, the carbon surfaces made the objects good absorbers of light, having extremely low reflectivity. The experiments showed that the photophoretic speed of the particles - which is on the order of several millimeters per second - varies depending on the particles' internal structure and associated variation in mass.

“Three quite distinct recent scientific novelties were combined in one experiment,” coauthor Andrei Rode of the Australian National University told *PhysOrg.com*. “[These are] the use of thermal, photophoretic forces to move particles in air, which is contrary to light pressure forces (radiation force) in optical tweezers in liquids; the use of optical vortex beams with a doughnut-like shape in the cross-section to form an optical vortex pipeline; and the use of light-absorbing particles with low thermal conductivity, such as agglomerates of carbon nanoparticles,and carbon coated glass micro-shells."

As the researchers demonstrated, the technique could enable the light-absorbing particles to be manipulated with a high degree of accuracy, even at large distances. The researchers could move particles to a target located 0.5 meters away with an accuracy of 10 micrometers, which they demonstrated using particles with diameters between 60 micrometers and 100 micrometers.

"The larger the distance, the more laser power is required, so the higher the danger of overheating or even burning particles," Rode said. "So the distance depends strongly on the particle properties. With the particles we used, there should not be a great challenge to move them up to a 10-meter distance."

Optically manipulating particles across such distances could have several applications, such as allowing for the touch-free transportation of containers holding dangerous or ultrapure substances, including viruses, living cells, and gases. As the scientists demonstrated, the technique enables researchers to move containers in opposite directions, accelerate them up to several centimeters per second, or hold them in a stationary place anywhere in the pipeline. Because the technique can be applied to a wide range of materials, it could also be used to study airborne particles such as atmospheric aerosols, as well as to model dusty plasmas and interstellar dust, among other applications.

More information: Vladlen G. Shvedov, et al. "Giant Optical Manipulation." *Physical Review Letters* 105, 118103 (2010). DOI:10.1103/PhysRevLett.105.118103