Optical trapping and manipulation: From the measurement of femtonewton forces to speckle optical tweezers

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Optical trapping and manipulation of micron-sized particles was first reported in the 1970s. Since then, it has found successful implementation in two different size ranges. At the sub-nanometre scale, light-matter mechanical coupling has enabled cooling of neutral atoms, ions and molecules, and the investigation of the quantum properties of ultra-cold gases. At the micrometre scale, the momentum transfer associated with the scattering of light allowed the manipulation of microscopic particles and biological entities of interest in fields as diverse as molecular biology, statistical physics and colloid science. However, it has been difficult to apply either of these techniques to the nanoscale, a size range of crucial importance for a wealth of potential applications based on technologically significant nanomaterials, such as quantum dots, nanowires, nanotubes, graphene and two-dimensional crystals. On one hand, nanoparticles are not amenable to conventional laser cooling because of their complex electronic structure. On the other hand, optical trapping forces acting on dielectric nanoparticles scale with volume, therefore can be easily overwhelmed by thermal fluctuations. Over the past few years, several novel approaches have been suggested to overcome such difficulties, with successful trapping demonstrated, e.g., for plasmonic nanoparticles, semiconductor nanowires and carbon nanostructures. Here, we review the state-of-the-art in trapping and manipulation of nanostructures with an emphasis on some of the most promising recent advances in fields such as controlled manipulation and assembly of individual and multiple nanostructures, force sensing at the femtonewton scale and next generation biosensors. Within this context, this talk will be focused on novel techniques for the measurement of nanoscopic forces using optically trapped probes (photonic force microscopy, total internal reflection microscopy), on the problems these techniques must overcome, and on the development of new light-propelled microscopic swimmers.

References:

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