

Optical trapping at the nanoscale with graphene plasmonic nanostructures

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Abstract

Optical nano-tweezers enables precise trapping and manipulation of nanoparticles and atoms at the nanoscale, which have important applications in quantum optics based on cold neutral atoms. We study the optical forces in graphene plasmonic nanostructures and show that the exploration of graphene plasmons provides the possibility of developing a new type of optical nano-tweezers with unprecedented trapping capabilities.

Optical tweezers have widespread applications. Conventional optical-tweezers are diffraction-limited. Extending optical trapping down to the nanometre scale will open unprecedented opportunities in many fields of science ranging from bioscience and quantum optics [1]. For example, in quantum information, manipulation of single, cold atoms with nano-accuracy is highly desirable [2]. Plasmonics provides an effective way to realized optical nano-tweezers and optical trapping based on metallic plasmonic nanostructures have been intensively studied. The intrinsic plasmons in graphene exhibit strong spatial confinement, remarkable enhancement of local electromagnetic fields and relatively low losses [3]. Graphene plasmonics are rapidly emerging as a versatile platform for manipulating light at the deep subwavelength scale. Here we show theoretically and numerically that the exploration of graphene plasmons provides the possibility of developing a new type of optical nano-tweezers with unprecedented trapping capabilities.

We investigated optical forces in various graphene plasmonic structures. We find that strong optical near-field forces can be generated under the illumination of mid-IR light when nanoparticles are located in the vicinity of a doped graphene film [4]. These strong forces are attributed to the excitation of graphene plasmons which lead to large optical gradients in the near field. For a graphene film patterned with nanoholes, the optical forces can generate an efficient optical trapping potential for dielectric particles with a diameter of less than 10nm which is three orders smaller than the wavelength of trapping light with an intensity of only a few $mW/\mu m^2$.

We also studied hybrid plasmonic structures where optical trapping at the nanoscale can be realized with the excitation of surface plasmons in metallic structures under the illumination of visible and near infrared light or with the excitation of graphene plasmons under the illumination of mid- and far-infrared light. This provides a versatile platform for trapping and manipulating nanoparticles/atoms with high accuracy and may be exploited for quantum optics based on cold neutral atoms.

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