Graphene based tunable nano-plasmonic infrared tweezers

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Abstract

Since the pioneer work by Ashkin, diffraction-limited focused beams have become a powerful method for manipulating micrometer sized objects [1]. Further extending this concept to effectively manipulate and control nanometer sized particles introduces new challenges. A major issue can be the large reduction of the total force with size which requires higher field intensities and smaller spot sizes. Fundamental limitations in focusing beams and practical limitations in increasing laser intensities make obtaining such highly confined fields in the nanoscale difficult [2]. An approach to elevate this issue is to apply well engineered structures to confine evanescent electromagnetic fields way beyond the diffraction limit [3]. In this work we are focusing on engineering nanostructured material to effectively control nanoparticles. The choice of Graphene as the material interface, in addition to supporting plasmons in the infrared spectrum adds a new tunability dimension to the nano-tweezers. In standard trapping apparatuses control of the position of the particle requires steering or changing the polarization of the incident beam. In plasmonic tweezers this is more difficult due to the dependence of the trapping process on the geometry [4]. However in this design Graphene's inherent tunability allows localized control over the trapping forces via electrostatic gates embedded on the structure. It is shown that the highly confined plasmons on the Graphene aperture allow a low powered beam (1 mW/um^2) to exert forces up to a few pico Newtons on the particle. Stable trapping is achieved for particle sizes from a few hundreds of nanometers down to 10 nm. In addition by slightly detuning the incident light from the resonance frequency, the structure has been optimized to have a self-induced back action feature (SIBA) effect to further reduce the intensity requirements [5]. We believe this design shows the capability of Graphene based nanoplasmonic structures to extend optical nanotweezers further for advanced multipurpose nanoscale functions such as ultra-accurate positioning and trapping, particle sorting, self assembly and maybe someday an integrated carbon based lab-on-a-chip.

References

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[3] Kern, J., et al., Atomic-Scale Confinement of Resonant Optical Fields. Nano Letters, **12(11)** (2012) p. 5504-5509.
[4] Kang, J.-H., et al., Low-power nano-optical vortex trapping via plasmonic diabolo nanoantennas. Nat Commun, **2**: (2011) p. 582.
[5] Juan, M.L., et al., Self-induced back-action optical trapping of dielectric nanoparticles. Nature Phys., **5**: (2009) p. 915-919.

Figures

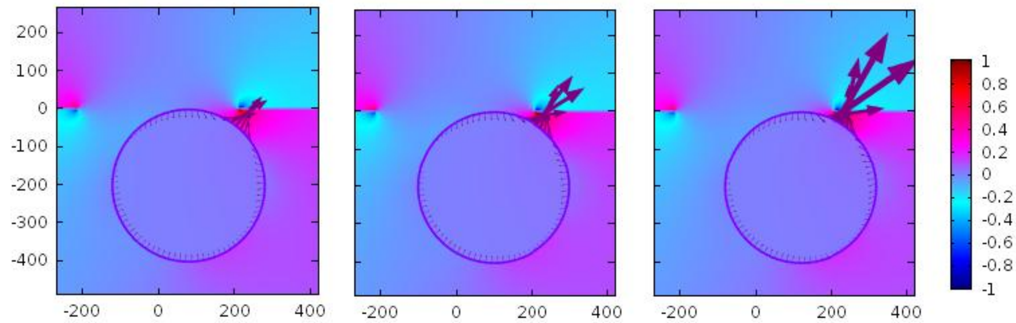

Figure 1 Trapping of a 400nm dielectric particle in the Graphene plasmonic trap. In this case the particles position progresses from 80 to 120 nm. Background is intensity (normalized) of electric field perpendicular to the Graphene sheet. Arrows are total time averaged electromagnetic force exerted on the particles surface

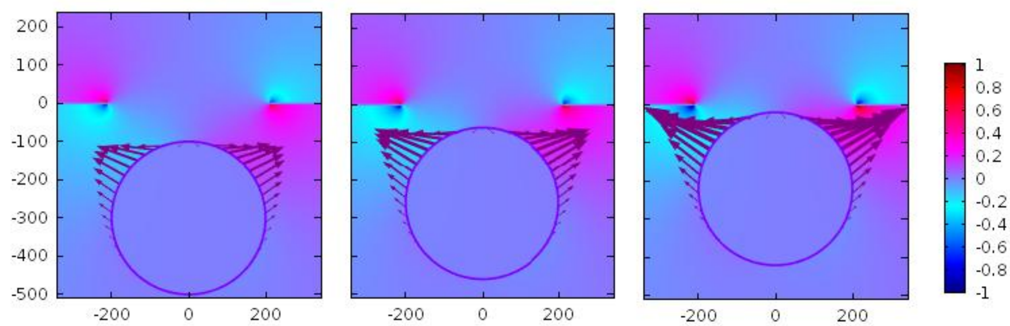

Figure 2 Trapping of a 400nm dielectric particle in the plasmonic near-field as it converses in the z direction from -300 to -220 nm. Here it is assumed the particle is moving along the x = 0 line. The total force is upwards, opposite to the direction of the incident wave and the scattering force

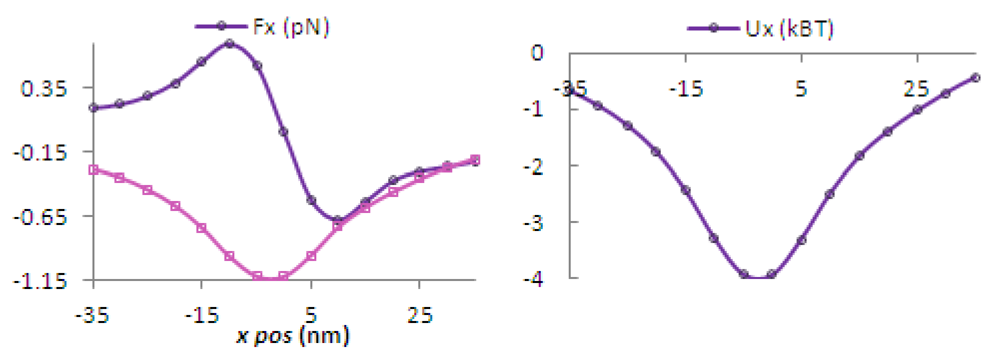

Figure 3 Total force (left) and optical potential (right) on a 20nm particle as it traverses in the x direction.

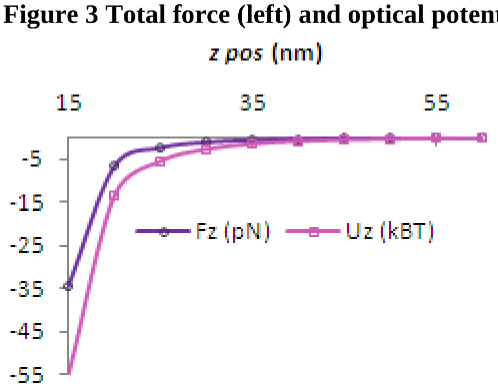

Figure 4 Total force and optical potential for a 20nm particle as it moves along the x = 0 and y = 0 line