Giant enhancement of optical trapping of rare-earth element doped nanoparticle

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1. ABSTRACT

The dominant force in optical trapping has been widely regarded from the particle size and the refractive index mismatch to its surrounding medium [1]. This poses the grand challenge for optical tweezers to trap nanoscale objects with the lower refractive index. Here we report that doping rare-earth ions into low refractive index nanocrystal can significantly increase its trap stiffness for optical trapping. We apply machine learning involved video tracking analysis on optically trapped nanoparticles to inspect their 3D trap stiffness. This method is valid for low-refractive index nanoparticles. We demonstrate the enhancement effect is enhanced with increased doping concentration. We demonstrate the steady trapping of a rare-earth ions doped nanoparticles with low refractive index 1.46, being doped with 20% of Ytterbium ions (Yb^{3+}). For a particle with an effective diameter of 22 nm, we achieved a high trap stiffness of 0.08 pN/μm/mW, more than 22 times higher than the simulated undoped particle. According to experimental result and simulation, we found the stiffness from surface charge enhancement [2] contributes 31%, while 6% stiffness contributed from the traditional electromagnetic interaction between photon and particle host. We further use the doped nanoparticle as force probes to label the membrane of a HeLa cell to enhance its trapping force, suggesting a much more efficient way for intracellular and intercellular manipulation.

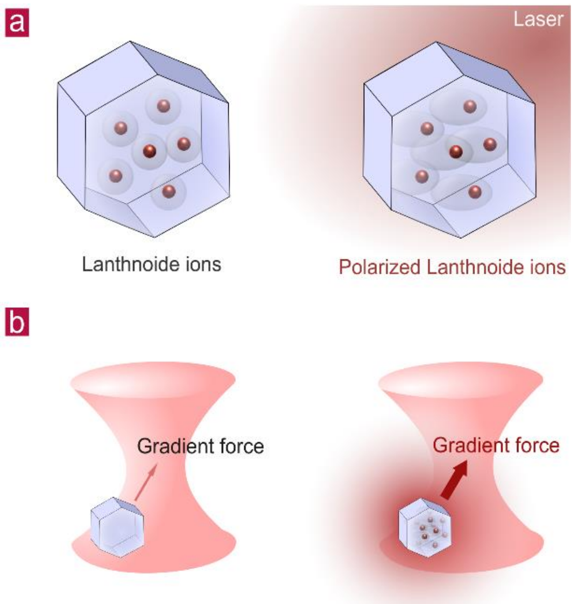

Figure 1. (a) Ion resonance effect in Lanthanoid ions doped nanoparticles (Ln-NPs). (b) Trapping Ln-NPs at resonance wavelength.

2. REFERENCES

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