Magneto-optical binding in the near field

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Abstract

In this work we show analytically and numerically the formation of a near-field stable optical binding between two identical plasmonic particles, induced by an incident plane wave.
The equilibrium binding distance is controlled by the angle between the polarization plane of the incoming field and the dimer axis, for which we have calculated an explicit formula. We have found that the condition to achieve stable binding depends on the particle's dielectric function and happens near the frequency of the dipole plasmonic resonance.
The binding stiffness of this stable attaching interaction is four orders of magnitude larger than the usual far-field optical binding and is formed orthogonally to the propagation direction of the incident beam (transverse binding).
The binding distance can be further manipulated considering the magneto-optical effect [1] and an equation relating the desired equilibrium distance with the required external magnetic field is obtained. Finally, the effect induced by the proposed binding method is tested using molecular dynamics simulations (see Figure 1).
Our study paves the way to achieve complete control of near-field binding forces between plasmonic nanoparticles.

REFERENCES

[1] Edelstein, S. et al. Magneto-optical Stern-Gerlach forces and nonreciprocal torques on small particles. Phys. Rev. Res. 1, 013005, DOI: 10.1103/PhysRevResearch.1.013005 (2019).

FIGURES

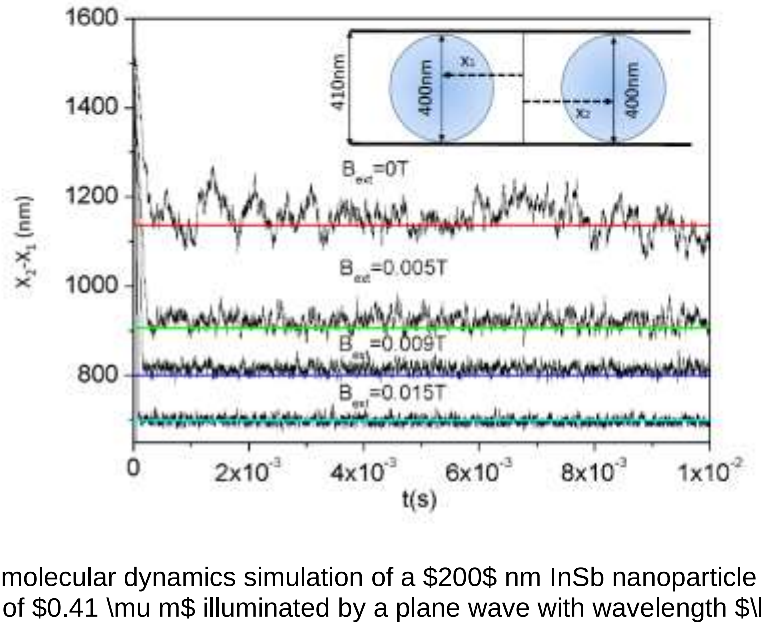

Figure 1: X-Y Langevin molecular dynamics simulation of a 200 nm InSb nanoparticle inside a micro-channel with a diameter of $0.41 \mu m$ illuminated by a plane wave with wavelength $\lambda=47.97 \mu$m, polarization angle $\theta=\arctan(\sqrt{2})$ and intensity $25 \mu W/nm^{2}$. Temperature is set to 293K. The simulation shows the particles separation versus time for different values of the external magnetic field. Straight lines correspond to the following expected equilibrium distances, $ R=1136$ nm (red), 906 nm (green) 800 nm(blue) 698 nm (cyan), obtained from the analytic expression Eq.\ref{Bext}. Inset shows an sketch of the particles configuration.