Hybrid approaches for nanoscale trapping and manipulation using plasmonic antennas

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Abstract

- Plasmonic antennas, utilizing localized surface plasmon resonances (LSPR), hold great premise for nanoscale trapping and in-situ spectroscopic analysis.
- Their effectiveness is hindered by photothermal effects in metallic nanoparticles, leading to repulsive thermophoretic forces.
- In this study, we present innovative strategies and hybrid approaches, including the utilization of double nanohole nanoapertures in metallic films and optically induced depletion attraction forces to tightly localize particles at the electromagnetic hotspots of plasmonic antennas.

Hybrid approaches for plasmonic trapping

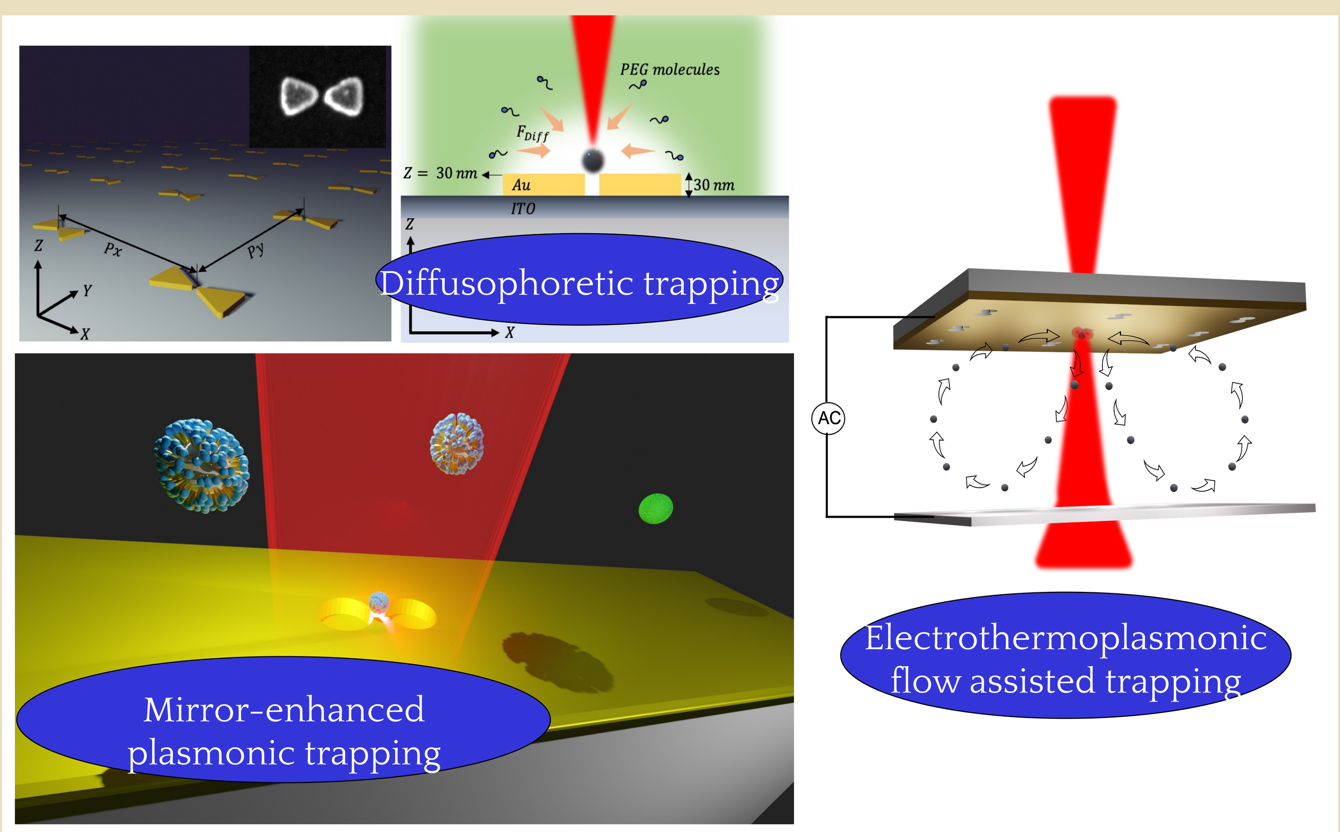

Figure 1. Hybrid approaches for nanoparticle trapping and dynamic manipulation using plasmonic antennas.

Electromagnetic simulations

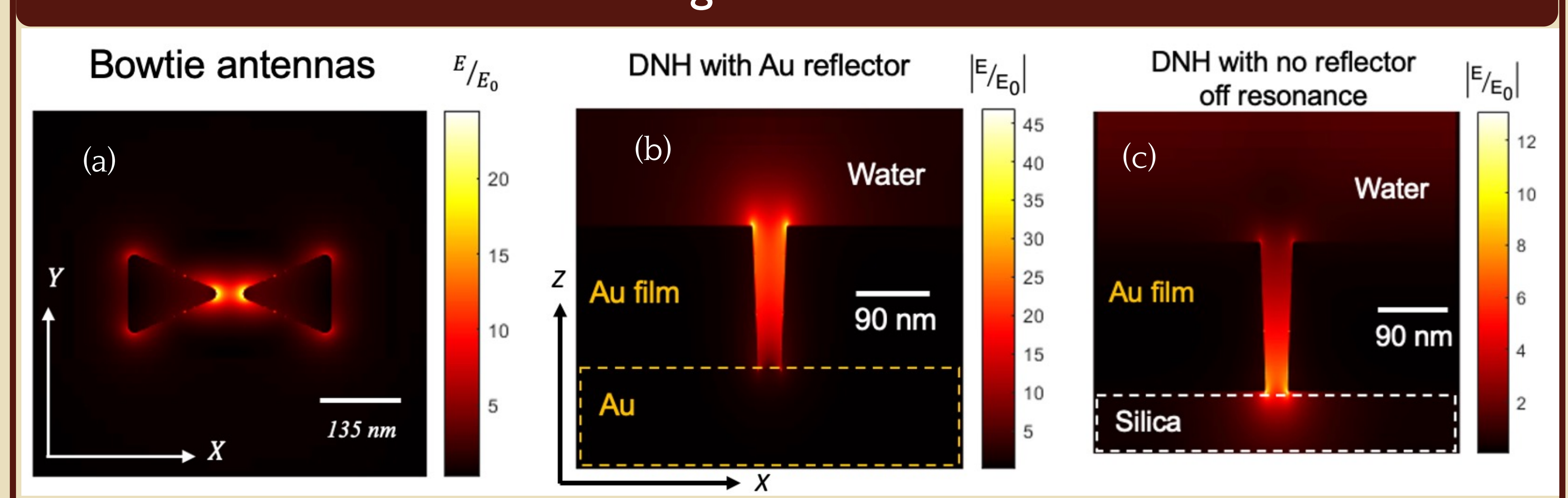

Figure 2. Electromagnetic simulations. (a) Bowtie antennas, (b) DNH with a reflector and (c) DNH without a reflector.

Temperature rise

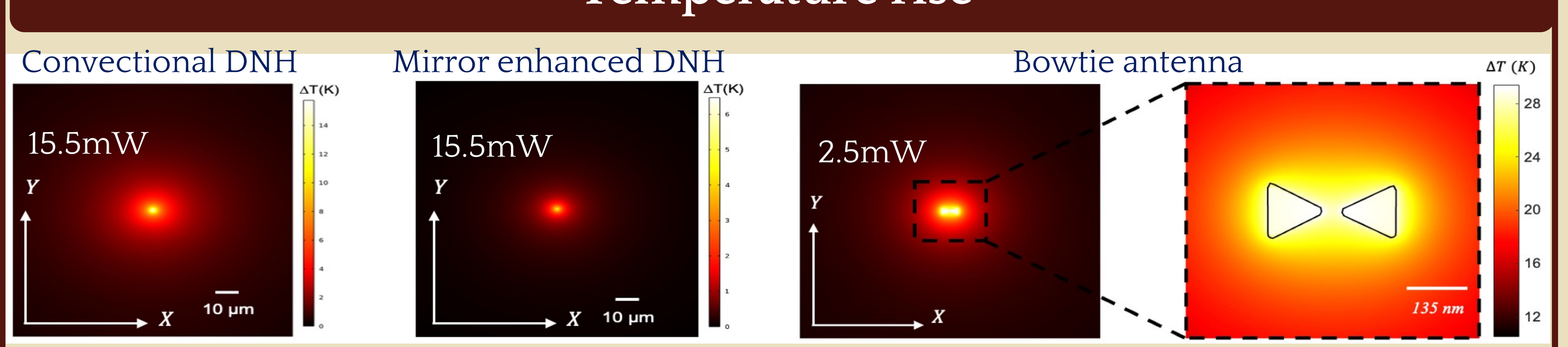

Figure 3. Thermal simulations.

Experimental results

ETP assisted trapping

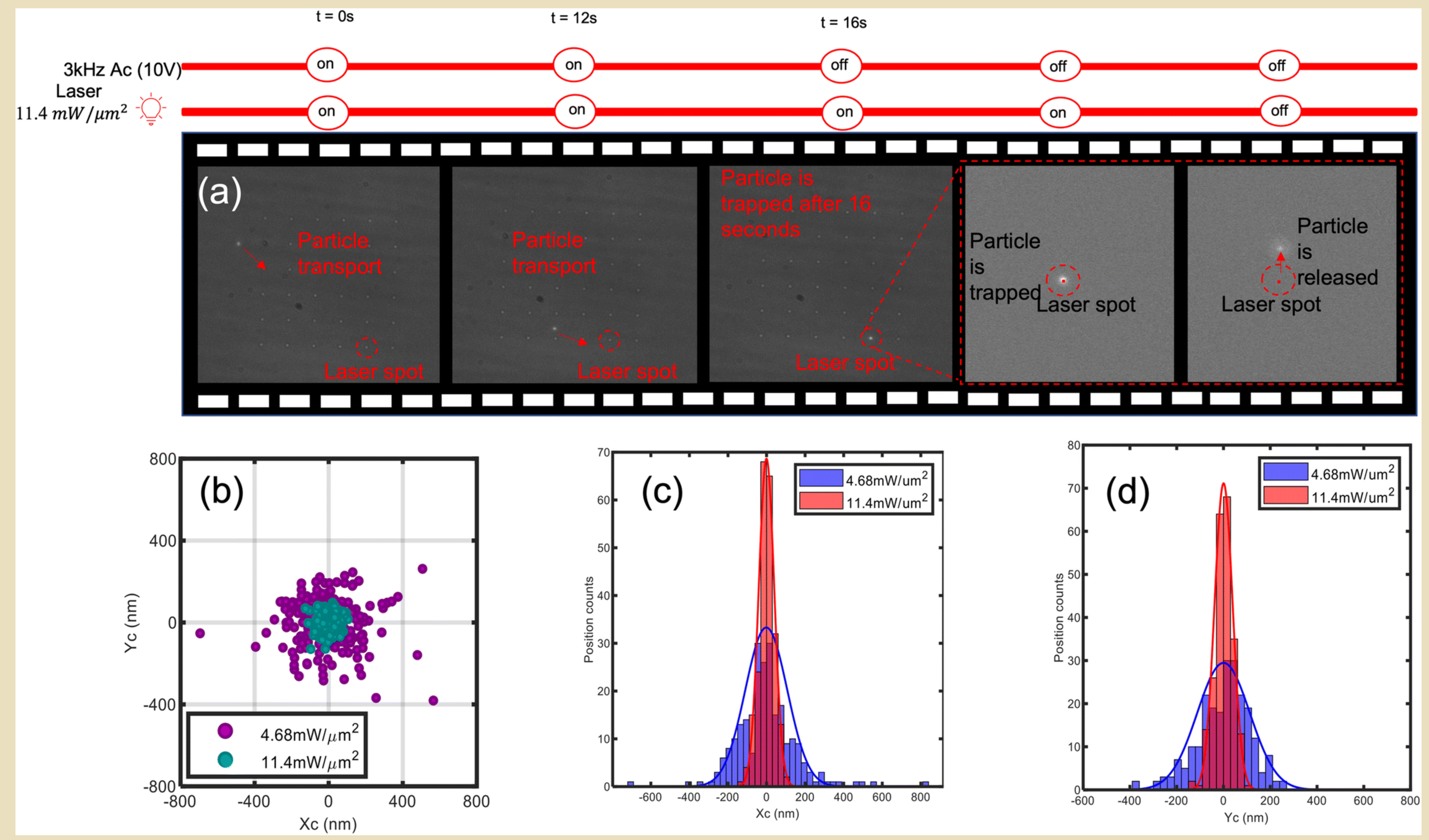

Figure 4. ETP transport and trapping of a 25 nm polystyrene particle. (a) ETP transport of a 25 nm polystyrene bead from a distance 63 µm away within 16 seconds (b) Particle displacement plot for a 25 nm polystyrene bead trapped at the plasmonic hotspot for two different laser intensities. (c) Particle position histograms for the position of the particle.

Mirror-enhanced trapping

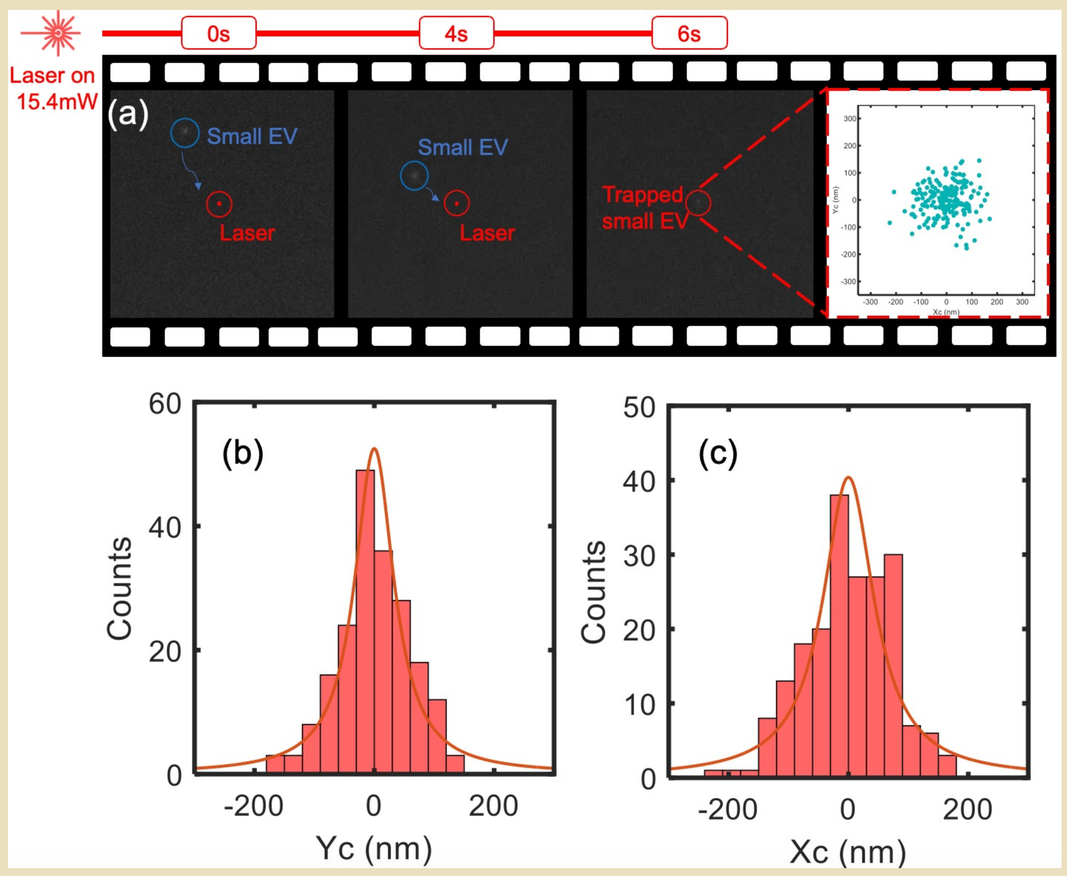

Figure 5. Trapping results for small EVs. (a) Trapping of small EV. (b) and (c) show the particle displacement histograms along the X and Y axes respectively.

Diffusophoretic trapping

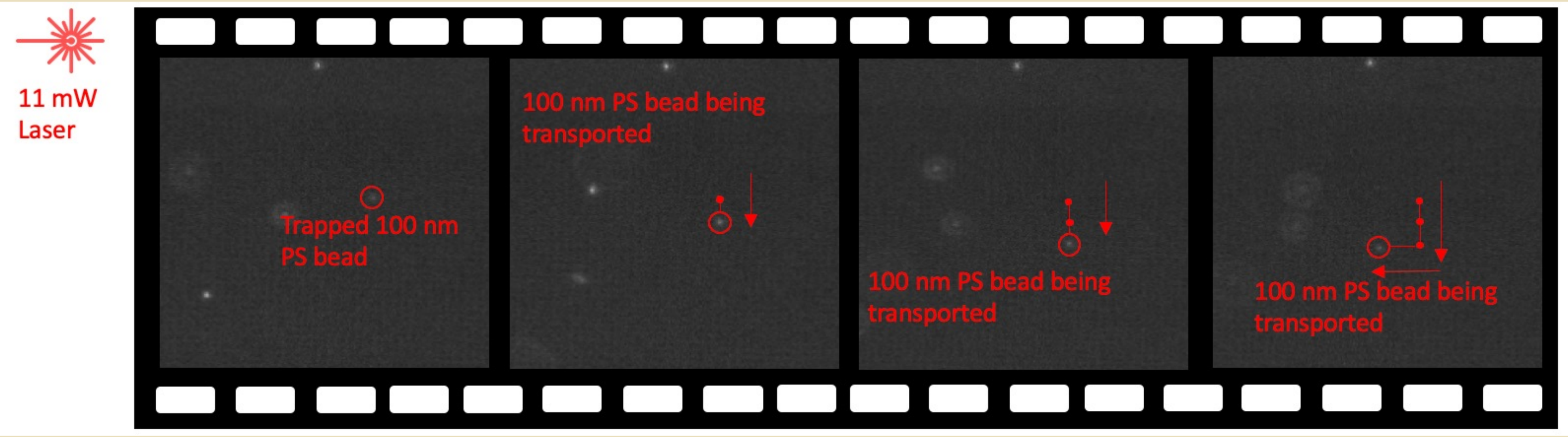

Figure 6. Trapping and dynamic 2D manipulation of a 100nm trapped particle is demonstrated under an 11 mW laser illumination, following an "L" shaped trajectory depicted through frames 1 to 4.

- ❑ We show that the ETP enabled trapping enables rapid transport and trapping particles as small as 20nm polystyrene beads.
- ❑ Dynamic manipulation is achieved by leveraging diffusophoretic forces induced by an array of plasmonic bowtie antennas.
- ❑ We show that by integrating a reflector with the double nanohole system, we can significantly decrease heating effects and maximize the field enhancement making them very attractive for applications that require enhanced light matter interaction.

Conclusions

- ❑ Our study demonstrates the effectiveness of Electrophoretic Trapping (ETP) in facilitating swift transport and trapping of particles, specifically showcasing its capability to capture particles as diminutive as 20nm polystyrene beads.
- ❑ The dynamic manipulation of particles is accomplished through the utilization of diffusophoretic forces generated by an array of plasmonic bowtie antennas. This technique allows for the precise and controlled movement of particles, showcasing the versatility of the system.
- ❑ In addition, our research reveals that the integration of a reflector with the double nanohole system yields substantial benefits. This integration serves to significantly reduce heating effects while simultaneously maximizing the field enhancement. This enhancement renders the system highly appealing for applications that necessitate an augmented interaction between light and matter, showcasing its potential in various scientific and technological domains.

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