The Hybrid Electrothermoplasmonic Nanotweezer: Shaping the Future of Nanomanipulation

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Introduction

Optical trapping[1] was invented by Arthur Ashkin at Bell Labs and have proven useful for manipulation of microscale objects and for ultrasensitive force measurements.

Limitations of Optical Tweezers:

- Does not enable high resolution particle trapping due to diffraction-limited trapping potential well
- Require relatively high laser power for stable particle trapping

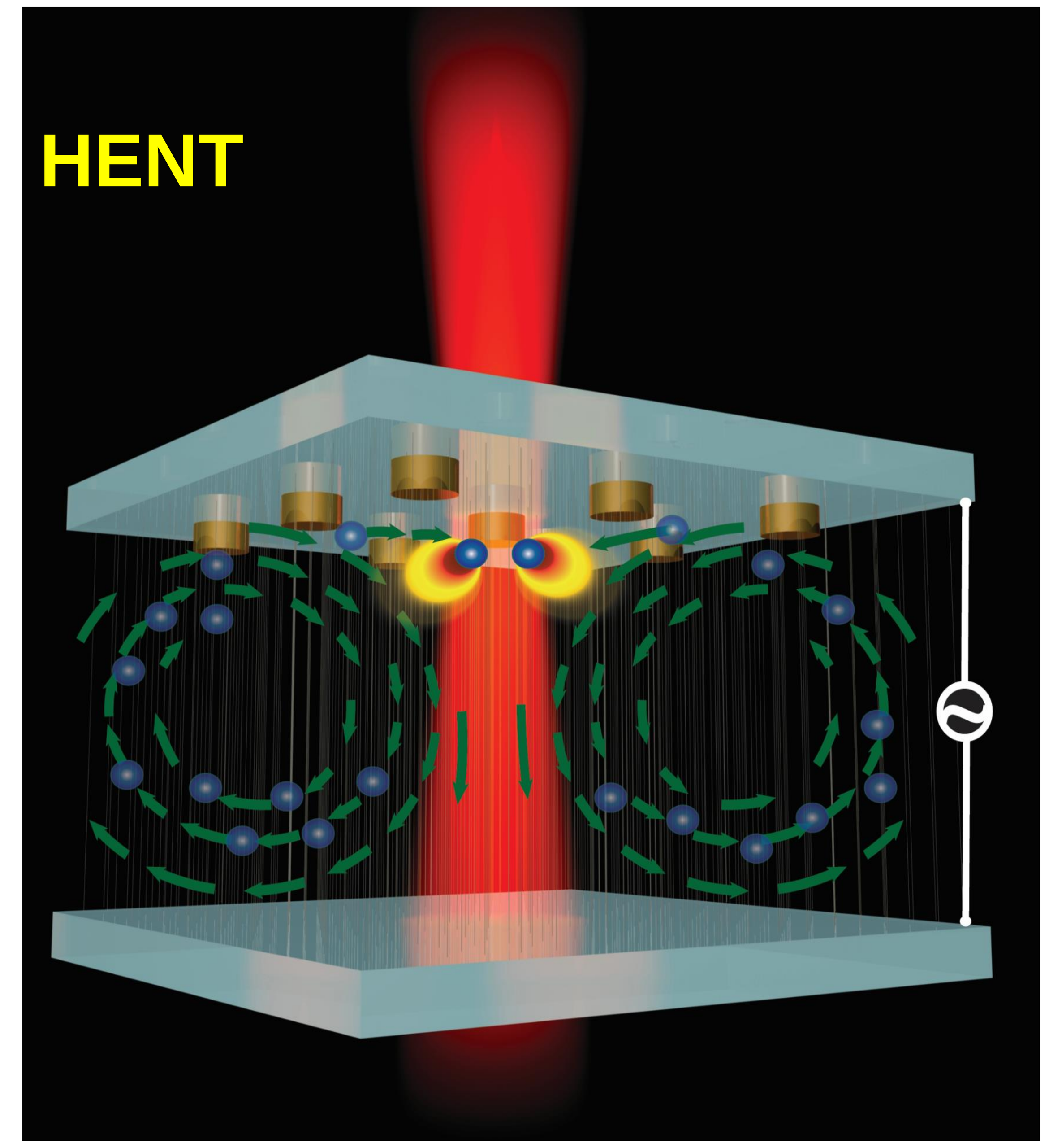
To address the aforementioned issues, Plasmonic Tweezers were developed

- Plasmonic nanoantennas can efficiently couple to propagating light to generate highly localized and enhanced electromagnetic field in the vicinity of the nanoantenna
- The enhanced and localized field provides strong optical gradient force and tight trapping potential well for stable trapping and confinement of nanoscale objects

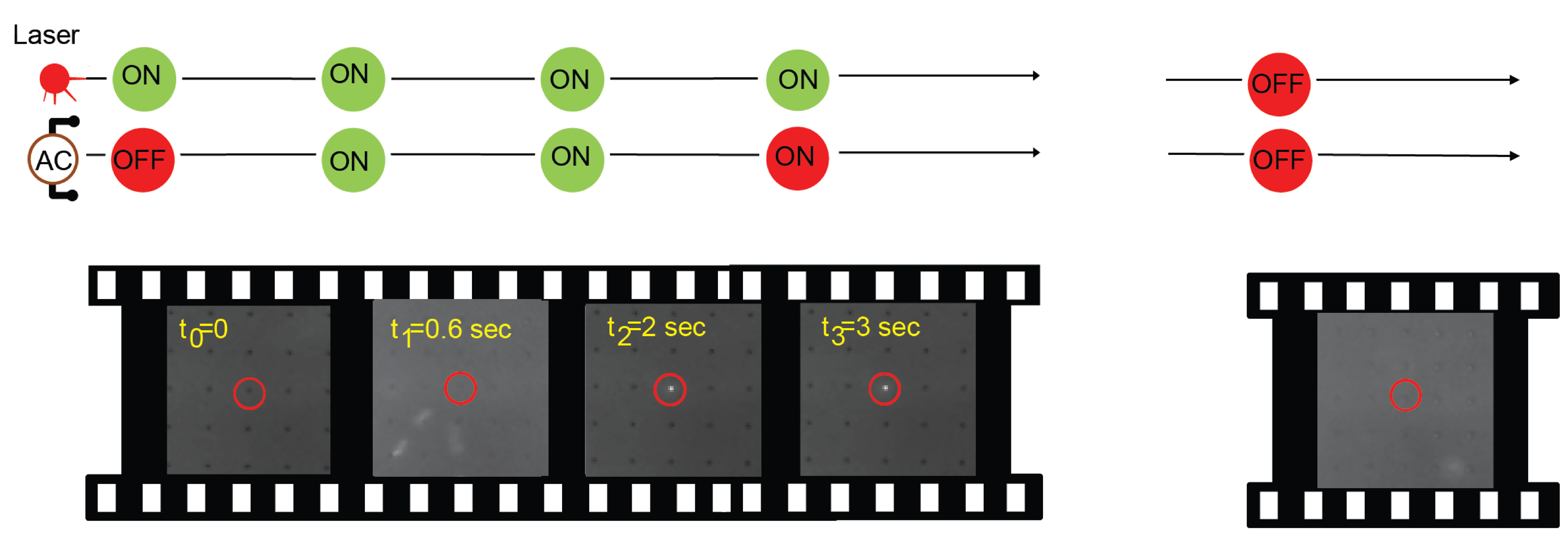
Limitations of state-of-the-art Plasmonic Tweezers:

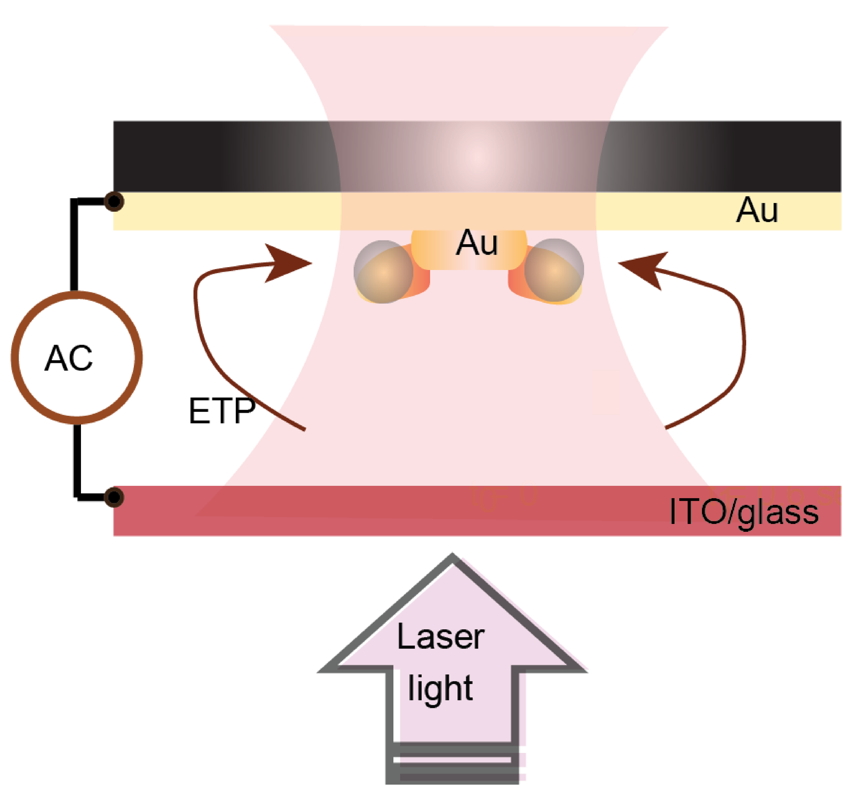
- Transport of particles to the plasmonic hotspots is slow and driven by Brownian diffusion.
- There is also the problem of loss of dynamic control of particles to be trapped.

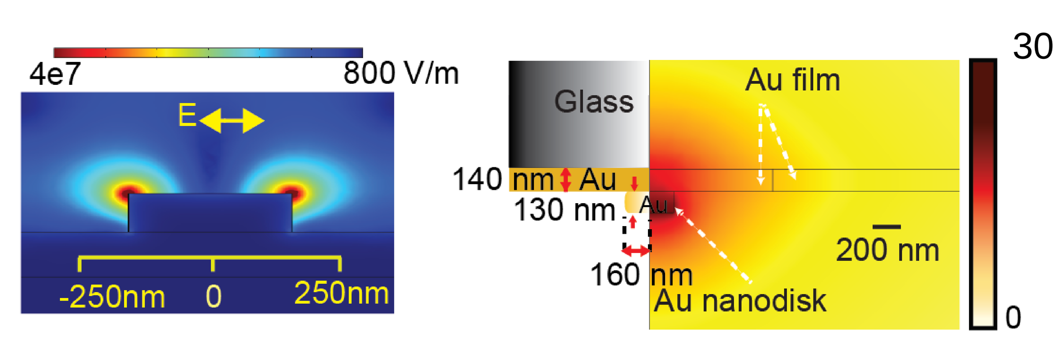
To address these limitations, we introduced a novel nanotweezer known as the Hybrid Electrothermoplasmonic Nanotweezer (HENT)

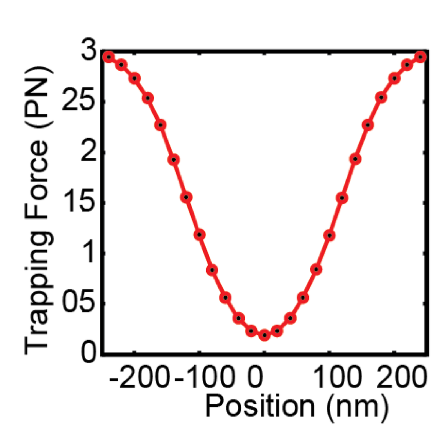


Hybrid Electrothermoplasmonic Nanotweezer (HENT)

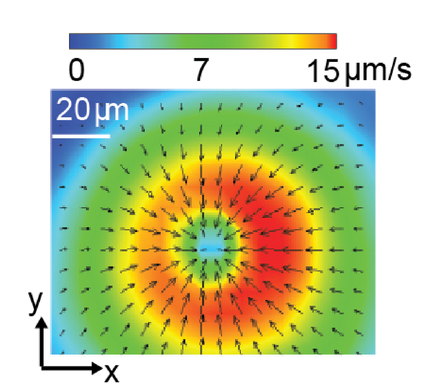








Optical trapping force

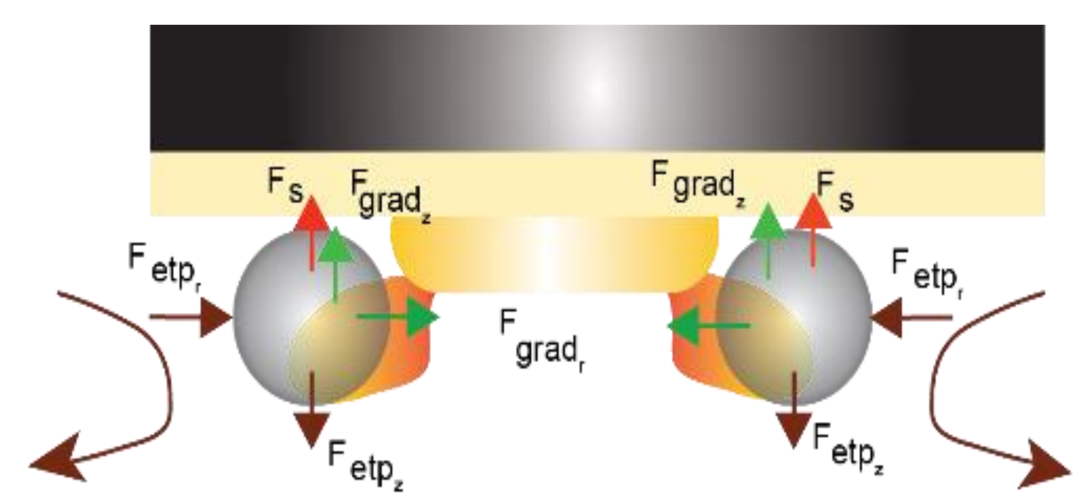


ETP flow radial velocity
Depicts well directed transport towards illuminated nanoantenna

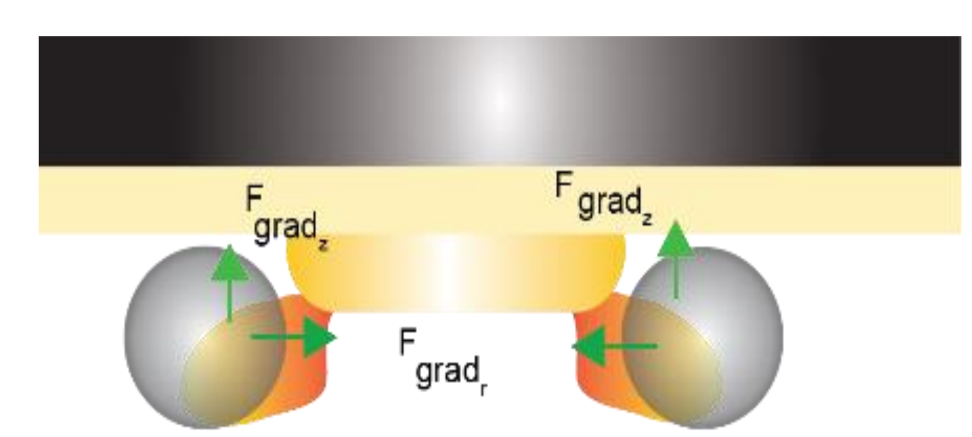
Features of HENT

- Rapid and precise delivery of nano-object to plasmonic hot-spots
- Complete control over particle dynamics

Trapping forces in HENT



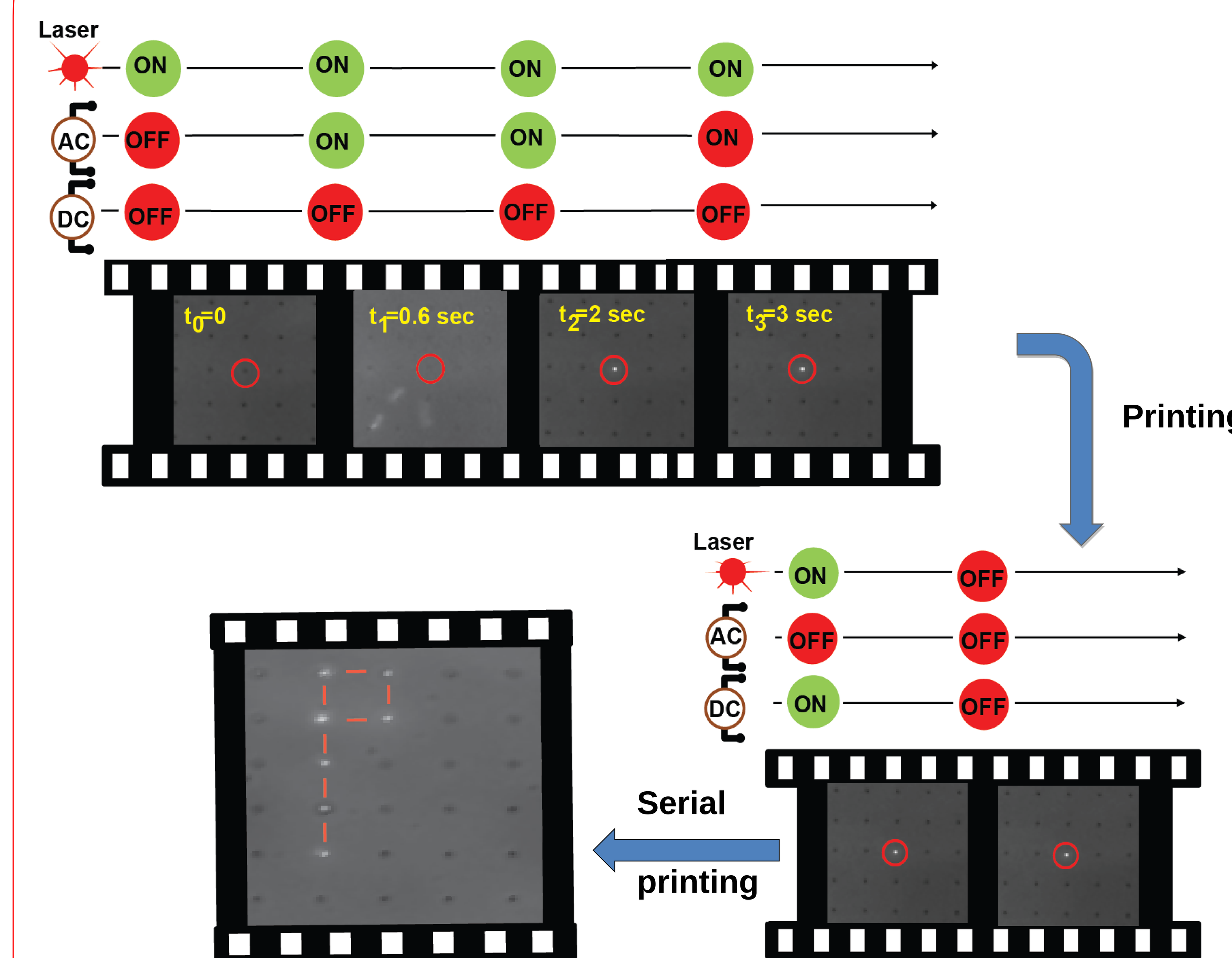
Hybrid Tweezing Mode: Laser ON, AC field ON



Plasmonic Tweezing Mode: Laser ON, AC field OFF

F_{grad} : Optical gradient force
F_{etp} : Electrothermoplasmonic fluid flow drag force
F_s : Particle surface interaction

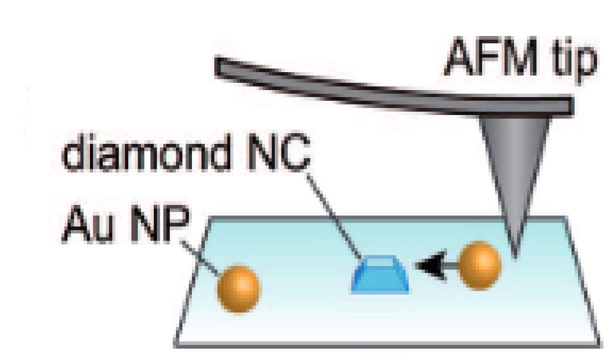
HENT-Assisted Additive Nanomanufacturing and Assembly (HAANA)



"P" for Purdue: The Alma mater of the first and last men to walk on the moon

Merits of HAANA over AFM-based manipulation:

- Simple platform, no need for complicated pick and place experimental setup
- Final particle destination is dictated by the position of the plasmonic hotspots
- Inherently robust against fabrication anomalies



AFM-based manipulation[3]

Conclusion

We have developed a novel paradigm for nanomanipulation known as (HENT) that enables:

- on-demand rapid and directional delivery of particles to the plasmonic hotspot(s) in the vicinity of a single illuminated plasmonic nanoantenna where they are trapped
- particle trapping in dilute media
- printing of nanoparticles on plasmonic hotspots

HENT would benefit a wide range of applications including bio-sensing, surface-enhanced spectroscopies, non-linear optics and quantum photonics

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References:
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