

## Dynamically swarming gold nanoparticles formed by laser trapping at glass/solution interface

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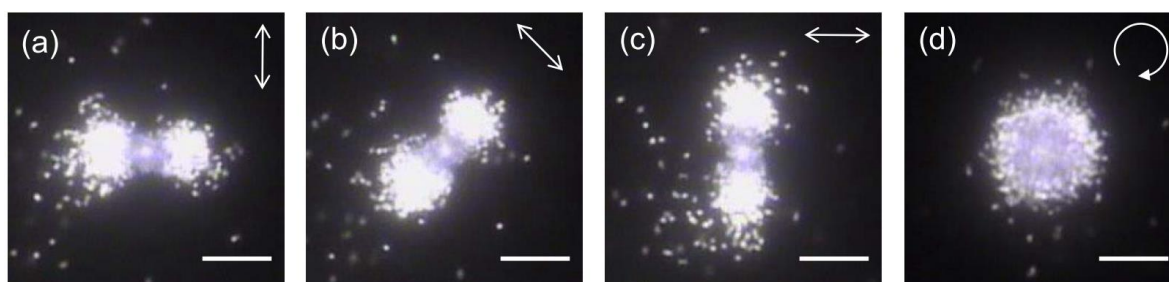
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Laser trapping has been utilized as tweezers to three-dimensionally trap nanoscale objects (such as dielectric nanoparticles, metallic nanoparticles, semiconductor quantum dots, proteins, molecular clusters, etc.) and has provided significant impacts in nanoscience and nanotechnology. The objects are immobilized at the position where the tightly focused laser beam is an irradiated area, and a prepared assembly is well arranged stably.

Here, we report that a single large assembly with dynamically swarming gold nanoparticles is formed by laser trapping at a glass/solution interface. The component nanoparticles dynamically interact with each other keeping their long interparticle distance, and their movement looks like swarms of the nanoparticles. Two swarms are directionally extended outside the focal spot, and the assembly is arranged perpendicularly to the linear polarization like a radiation pattern of dipole scattering (Fig. 1(a-c)). On the other hand a doughnut shaped swarm is prepared by circularly polarized trapping laser (Fig. 1(d)). The light field is expanded as scattered light through the trapped nanoparticles, this modified light field further traps the nanoparticles, and scattering and trapping cooperatively develop. Due to these nonlinear dynamic processes, the dynamically fluctuating swarms are evolved up to few tens micrometer. This finding will open a way to create various swarms of nanoscale objects which are interacted and bound through scattered light depending on properties of laser beam and nanomaterials.



**Figure 1.** Dark-field scattering images of gold nanoparticle assembly formed by laser trapping at glass/solution interface with tightly focused laser beam. (a-c) The direction of the linear polarization is vertical, 45 degree-tilted, and horizontal, respectively. (d) The gold nanoparticle assembly formed by circularly polarized light. The size of the particles is 200 nm in diameter, and they are suspended in water. The laser wavelength and laser power after the objective lens is 1064 nm and 60 mW, respectively. Arrows denote the direction of light polarization, and the length of the white bars is 10  $\mu$ m.