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The dance of hot nanoparticles

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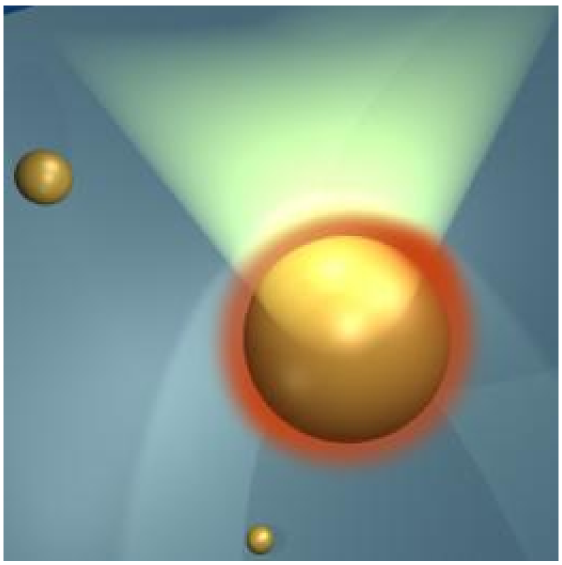

Heated nanoparticles "shine" in their solvent. Image credit: Daniel Rings

(PhysOrg.com) -- "Brownian motion is a very old concept," Klaus Kroy tells *PhysOrg.com*. "The laws explaining it were formulated more than a century ago by Albert Einstein. However, we are finding some interesting divergences from what has been known for all these years." Brownian motion is the random movement of small particles dissolved in a liquid or gas. It is the result of the particles' collisions with the solvent molecules.

Kroy is a theoretical physicist at the University of Leipzig, Germany. Together with his experimental colleague, Frank Cichos, also at the university, he investigated the non-equilibrium Brownian motion of hot nanoparticles, so-called "Hot Brownian motion". The team's work has been published in Physical Review Letters.

When Einstein wrote his seminal paper in 1905, he assumed that a particle would be at the same temperature as the solvent. However, this doesn't take into account how a heated particle affects the surrounding solvent. For anyone interested in trapping or tracking nanoparticles with light, this idea of Einstein's has to be reinvestigated because the particles heat up due to optical absorption.

Kroy, Cichos and their colleagues used a focused laser to heat gold nanoparticles suspended in water and observed what happened. The result of the experiment showed that the viscosity and temperature "felt" by the heated nanoparticle are not the surface conditions. Instead, the values that relate to the hot Brownian motion need to be calculated over the whole solvent, as predicted by the new theory put forward by the team.

Using this theory, it becomes possible to precisely control and manipulate the way the nanoparticles move in the liquid. "We show how to use the temperature to speed the particles in the liquid. Brownian motion is doing all the action, but we can use a laser aimed at the particles to change how fast they are moving," Cichos says.

One of the ways to direct the motion is to prepare asymmetric particles that have gold on only one side. "A heat kick comes from the one side," Cichos explains, "and this can be exploited for moving particles around with a laser." Similarly, other groups have exploited the heating of nanoparticles stuck in a biomembrane to mobilize them. "The trick will also work with other frozen matrices that can be molten by the heat emitted from the nanoparticle," he explains.

Biology offers ample opportunities for applications of new photothermal technologies. Many researchers in biology use nanoparticles as markers. They can be attached to biomolecules and cell organelles, and their transport can then be tracked inside a cell, or anywhere else in a living organism. “However, you need to be able to see these tiny particles,” Cichos says. At Leipzig University, the team modulated the heat of the laser to make the nanoparticles “shine” periodically. It works like a lighthouse, so that the nanonparticles can be detected virtually without perturbing background noise, offering an alternative to some of the current methods used to make biomarkers visible.

Another benefit of the new developments from Germany includes the fact that they provide the basis for a quantitative analysis of all experiments that use light to confine particles. “The trapping of nanoparticles with optical tweezers has become indispensible for many experiments and applications,” Kroy points out. “But to gain a precise control over this technique, we first need to understand how hot particles move. This is why we are shedding some more light on Brownian motion , showing that there is still more to learn.”

More information: Daniel Rings, Romy Schachoff, Markus Selmke, Frank Cichos, and Klaus Kroy, “Hot Brownian Motion,” *Physical Review Letters* (2010). Available online: link.aps.org/doi/10.1103/PhysRevLett.105.090604