Can a single molecule behave as a mirror?

November 18 2008, By Miranda Marquit

(PhysOrg.com) -- “We have shown for the first time, theoretically, that a single molecule can behave as a perfect mirror,” Mario Agio tells *PhysOrg.com.* “Imagine that your mirror at home becomes a single molecule and that you put a strong lens between you and it. Well, you could still see the image of your face reflected…[A]mazing if you think that a molecule is just about a nanometer in size.”

Agio is a scientist at the Nano-Optics Group headed by Vahid Sandoghdar at ETH Zurich, Switzerland. Sandoghdar’s team investigates both theoretically and experimentally how light interacts with nanoscale objects. “Theoretically,” Agio says, “we show that a directional dipole wave can be reflected by one point-like oscillating dipole.” The results of the work done by the Group, including Gert Zumofen and Nassiredin Mojarad, can be seen in *Physical Review Letters:* “Perfect Reflection of Light by an Oscillating Dipole.”

“There are many possibilities for this kind of work,” Agio points out. He explains that, “Once you can realize efficient coupling between a photon and a molecule or atom in free space, there is a great deal that you can do. For example, advanced solar cells, spectroscopy, quantum communications and quantum computation would all benefit from stronger interaction between light and matter.”

However, there are some technical problems that need to be overcome in the lab. One of the more pressing issues is the fact that molecules behave like strongly damped oscillators at room temperature. “We need to cool the system to very low temperatures,” Agio says. Referring to work

published earlier this year in *Nature Physics* ("Efficient coupling of photons to a single molecule and the observation of its resonance fluorescence"), he continues: "Indeed, our experiments have been able to achieve 12 percent extinction of light in the forward direction by a single molecule.

Agio also explains that there are problems with being able to focus. "The reflection is only 100 percent if you can create a focused beam with lenses that just are not available today. But a terrific 80 percent reflection should be possible even with today's conventional lenses and laser beams."

Sandoghdar's group has been considering future developments for this work, and Agio discusses some of the possibilities. "We are considering the use of optical antennas to overcome the limitations of focusing. We should be able to channel and collect light more efficiently, improving the coupling between a photon and a single molecule, very much in the same way the antenna in your cell phone receives and send calls." He pauses before adding: "We'd have to make it very small, though, scaling everything down to optical frequencies is challenging."

Agio is optimistic. He points out that the group has already done some work along the lines of optical antennas, and that it, too, has been reported in Physical Review Letters. "We have already shown experimentally that noble metal nanoparticles are very efficient optical antennas for single molecules," he says, referencing an article titled, "Enhancement of single molecule fluorescence using a gold nanoparticle as an optical nano-antenna."

"Now," he continues, describing the next steps, "we are working on how to combine the focusing with the antenna to make all of this workable."

More Information:

G. Zumofen, N. M. Mojarad, V. Sandoghdar, and M. Agio. “Perfect Reflection of Light by an Oscillating Dipole,” Physical Review Letters (2008). Available online: link.aps.org/abstract/PRL/v101/e180404.

G. Wrigge, I. Gerhardt, J. Hwang, G. Zumofen & V. Sandoghdar. “Efficient coupling of photons to a single molecule and the observation of its resonance fluorescence,” Nature Physics (2008). Available online: www.nature.com/nphys/journal/v … n1/abs/nphys812.html.

Sergei Kühn, Ulf Håkanson, Lavinia Rogobete, and Vahid Sandoghdar. “Enhancement of Single-Molecule Fluorescence Using a Gold Nanoparticle as an Optical Nanoantenna,” Physical Review Letters (2006). Available online: link.aps.org/abstract/PRL/v97/e017402.