**http://www.optoiq.com/index/photonics-technologies-applications/lfw-display/lfw-article-display/371310/articles/optoiq2/photonics-technologies/applications-\_\_markets/science-\_\_research/applied-optics/2009/12/optical-trapping-trapping-near-resonance-could-reduce-biological-damage.html**

**OPTICAL TRAPPING: Trapping near resonance could reduce biological damage**

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The two forces associated with [optical trapping](http://www.laserfocusworld.com/articles/302490) are the scattering force in the direction of beam propagation and the gradient force in the direction of the gradient of light due to the highly focused beam. The gradient force must overcome the scattering force to allow stable, conventional single-beam optical trapping, and it does so when the particle is trapped far from resonance on the red side of the spectrum (assuming the focus is very tight and optical power is high enough). For these reasons (and also because lasers are more commercially available here), optical trapping and tweezing is most frequently carried out far from any optical-absorption resonance.

Typically, polystyrene or silica beads on the order of 2 µm in size, which exhibit resonances in the UV or blue wavelength regions, are trapped using lasers from the green to the IR part of the spectrum. However, near-resonant trapping is used extensively in laser cooling and trapping of much smaller neutral atoms–so why shouldn’t these properties apply to somewhat larger particles? To discover the answer, and to better understand the mechanisms behind wavelength-dependent and near-resonant trapping, Brooke Hester from the National Institute of Standards and Technology (NIST; Gaithersburg, MD)–a Ph.D. candidate in the Chemical Physics program at the University of Maryland who is doing her dissertation research at NIST–performed trapping experiments using a home-built microscope trapping apparatus (see figure).1

**Why near-resonant trapping?**

Both the gradient and scattering optical forces are predicted to be strongest near the resonance absorption of a trapped Rayleigh particle (a particle much smaller than the trap wavelength). But the gradient force (the force responsible for holding the particle near the focus) is maximized when it is red-shifted from the resonance peak. Basically, the force responsible for trapping should be the strongest if the correct trap wavelength is chosen. If this is true, says Hester, then near-resonant optical trapping of single Rayleigh particles would require less optical power than the typical far-resonant optical trapping.

Most optical-tweezing experiments use a trapped particle as a marker attached to some other entity of interest such as a DNA strand or protein. Properties of the particle of interest can be measured by exposing it to some force or other stimuli, and its reaction can be tracked by recording the response of the attached, optically trapped object. Because these experiments take place in biological environments, the lower the laser power, the better–especially in the case of optical tweezers that focus a large amount of optical power into a tiny volume. So if researchers can use these Rayleigh particles in a near-resonant trapping configuration, they could prevent damage to delicate biological specimens.

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| [[http://images.pennnet.com/articles/lfw/thm/th_optical%20%201109%2001.jpg](javascript:OpenLargeWindow(265014,650,666,'IS');)](javascript:OpenLargeWindow(265014,650,666,'IS');) *[A microscope apparatus is being used at NIST to understand differences between near-resonance and far-from-resonance trapping and tweezing of particles. The study could improve the prospects for near-resonant trapping at lower power levels, to limit damage to biological specimens. (Courtesy of NIST)](javascript:OpenLargeWindow(265014,650,666,'IS');)*  [Click here to enlarge image](javascript:OpenLargeWindow(265014,650,666,'IS');) |

In addition, if higher forces are present near resonance, this effect could be exploited for optical-sorting experiments in which a researcher could trap certain near-resonant particles but not others whose resonance is far from the wavelength of the laser trap.

**Observations and findings**

In the experimental setup, a single-focus TEM00 Ti:sapphire Trestles laser from Del Mar Photonics (San Diego, CA) is used for optical trapping. The tiny particles used in the experiment are [gold nanoshells](http://www.laserfocusworld.com/articles/357338), fabricated by Naomi Halas and her Nanophotonics group at Rice University. Chemical techniques are used to coat nanoscopic silica spheres with a thin and even layer of gold. The thickness of the gold shell and the size of the silica sphere determine the location and width of the resonance peak in the extinction spectrum of the gold nanoshell. These dimensions can be manipulated with extreme sensitivity, allowing the researchers at Rice to synthesize nanoshells with resonances from the visible to the IR.

For this study, the resonances of the four nanoshell species are 650, 755, 790, and 1100 nm. Preliminary experimental results show that lower laser power is required to trap a nanoshell nearer the red side of the spectrum compared to far-from-resonance trapping. For example, for a nanoshell with a resonance at 790 nm, lower laser power is required for trapping between 790 and 860 nm compared to trapping at 1064 nm, and this required power decreases as the trapping wavelength approaches 790 nm. The trapping wavelength range is limited only by the wavelength range of the laser.

Hester says that further experiments will quantify this effect near to, far from, and at resonance, and will focus on the effects of nanoshell heating in optical-tweezer experiments.   
  
***–Gail Overton***

**REFERENCE**

1. B. C. Hester et al., OSA Frontiers in Optics conference, poster paper JWC60, San Jose, CA (Oct. 14, 2009).