

# Scatterings

TYLER KRUPA

## Stationary Light Created Within Nanostructures

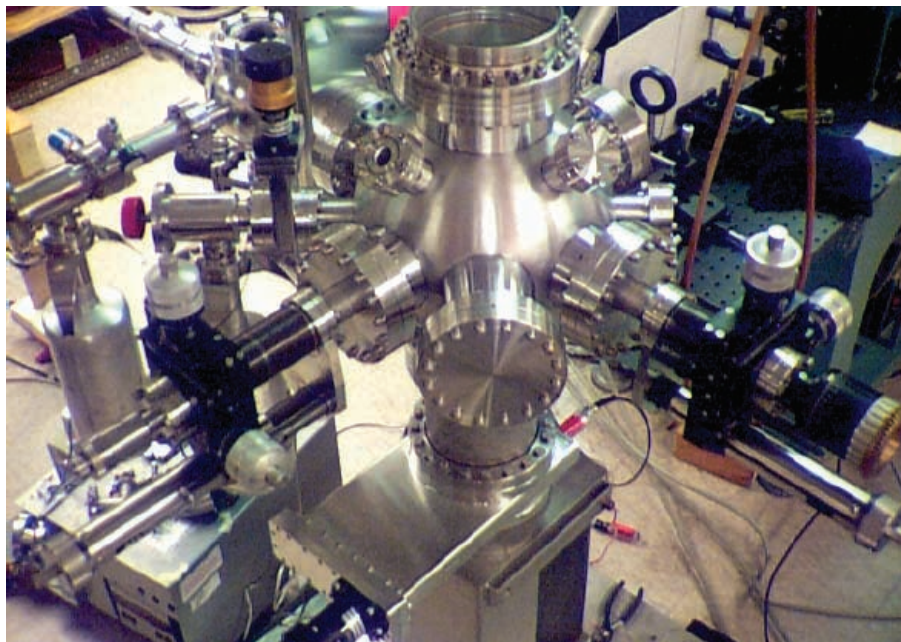
Researchers at the University of Michigan College of Engineering, led by Stephen Rand and Richard Laine, have recently generated stationary light within a random medium that oscillates in time but does not move through space. The results mark the first experimental verification that non-propagating light can produce laser action in strongly scattering media, using the strong localization effect predicted in the 1950s for electron waves by Phil W. Anderson.

“Other research groups have done similar things with coherent control techniques to slow down or stop light,” said Rand, a professor of applied physics. “However, this is the first method in which light is generated as a stationary excitation from the very beginning.”

The research team achieved this result by first synthesizing nanopowders with an inexpensive flame spray pyrolysis technique. Light generated by rare earth atoms using electron excitation of nanoparticles as small as a fiftieth of the optical wavelength was shown to remain within a wavelength of its point of origin by being repeatedly bounced back and forth between the densely packed, reflective particles. This created a nano-sized “hall of mirrors” that provided feedback and amplification of light. Lasing was observed in an ultrahigh vacuum chamber as the result of trapped light “leaking” from regions near the powder surface. The laser output was both incoherent and omnidirectional.

Using this method, the research team demonstrated the first continuous-wave (cw) random laser in which the light experienced feedback characteristic of a cavity even though no physical cavity was apparent. According to Rand, this is the first random laser to exhibit the optical properties expected of a strongly localized light source in which electromagnetic transport is completely absent.

“This is exciting for all phosphor-based lighting applications because the intro-



Ultrahigh vacuum chamber used by the University of Michigan team to observe lasing.

University of Michigan College of Engineering

duction of laser phosphors removes the fundamental limitations on the brightness imposed by spontaneous emission rates,” said Rand.

The technology, which is being commercialized by TAL Materials (Ann Arbor, Michigan), will be used to create improved fluorescent lights, advanced televisions, and flat panel displays.

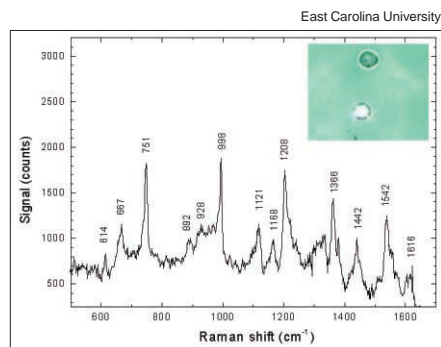
## Optical-Trapping System Tested on Living Cells

Scientists at East Carolina University (Greenville, North Carolina) led by Yong-qing Li, have developed a compact laser tweezers Raman spectroscopy (LTRS) system that provides real-time spectroscopic measurements of living cells. The system, which was tested on single red blood cells and yeast cells placed in an optical trap, combines the advantages of near-infrared (NIR) Raman spectroscopy and optical tweezers using a low-power semiconductor laser.

“This is the first LTRS study performed on living cells,” said Li, a faculty member

in the university’s Department of Physics. “Since the system was specifically designed for biology applications, high sensitivity can be achieved without harming the cells.”

In the initial experiment, single red blood cells and yeast cells were placed in an optical trap and spectrally characterized. The LTRS system, which was calibrated with polystyrene microbeads, used a low-power diode laser (785 nm) for both laser trapping and Raman excitation. To avoid thermal damage, the laser was programmed to operate at low power (~2.0 mW) when a cell was trapped.



Raman spectra of a red blood cell captured in an optical trap in saline solution. Inset: Image of the trapped cell.

To obtain Raman measurements, the laser power was increased to 20 mW for approximately two seconds to ensure high-excitation intensity. Once the Raman spectra were acquired, the laser was once again returned to low-power operation for trapping.

A spectrograph equipped with a front-illuminated, charge-coupled device then collected the Raman spectra while a video camera system recorded the images of trapped cells.

Using the LTRS system, the research team successfully trapped and recorded the Raman spectra for both single red blood cells and yeast cells. The hemoglobin concentration inside the red blood cells was also determined.

“The design of the LTRS system allowed sufficient excitation power for Raman spectroscopy while avoiding photochemical or thermal damage to the biological samples,” said Li. “The spectra were obtained in real-time and were identical to those of assigned and published bands.”

The research team also used the LTRS system to detect the spectroscopic differences between a living yeast cell and a dead yeast cell. The living yeast cells were first cultured in an aqueous solution at room temperature. To prepare the dead yeast cells, the research team placed a tube of living yeast cell solution into boiling water for ten minutes and gradually cooled the tube to room temperature. The living and dead yeast cells were then placed in an optical trap and analyzed with the LTRS system. As expected, a significant difference in the Raman spectra was observed for the different cells.

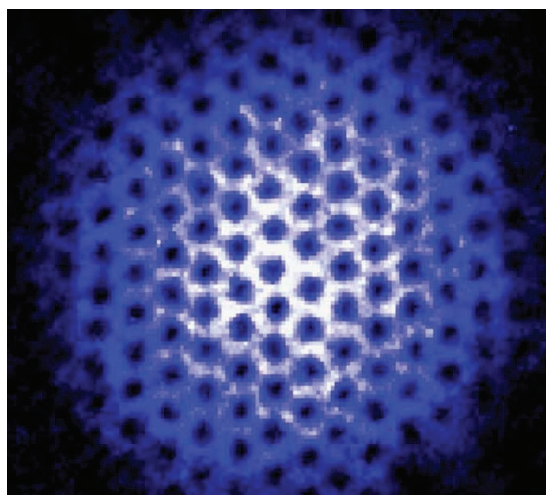
“The results showed that the boiling water killed the yeast cells and changed their histology and molecular configuration,” said Li. “These structural differences could be easily recognized by observing the characteristic bands of the Raman spectra.”

According to Li, the results of the two experiments show that the LTRS system is uniquely suited to obtaining the molecular information of *in vitro* single biological cells.

With further testing, Li predicts that the system will become a valuable tool in the study of fundamental cellular processes and the diagnosis of cellular disorders. The research team is already using the LTRS system to study *Escherichia coli* and human breast cancer cells.

## Technique Gives Atoms a Novel Spin

Researchers at the University of Colorado have developed a technique that rotates trapped clouds of atoms in Bose-Einstein condensate (BEC) superfluid vortex lattices. The technique, which does not use the rotating bucket associated with liquid helium experiments, evaporated



University of Colorado

Vortice image obtained in the experiment. Vortices tended to order themselves in hexagonal Abrikosov lattices because of the forces of mutual repulsion.

rates atoms in a single dimension to create condensates with extremely high levels of vorticity and rotation.

“Although vortices have been excited in BEC through a variety of techniques, the mechanisms by which they are formed still pose fundamental questions,” said Ian Coddington, a researcher at the University of Colorado’s BEC group, which is led by Eric Cornell, one of the three recipients of the 2001 Nobel Prize in physics. “By completely removing the rotating bucket and just looking at the excitations caused by the normal, non-condensed fluid, we have developed the first technique that isolates the effect of the normal component on the environment of vortices.”

The researchers started with a normal cloud that was considerably hotter than the temperature below which a BEC forms, and stirred it in an elliptically shaped, rotating trap that was magnetic, with smooth walls. (The trap was elliptical in the x-y plane and rotating about z.) When the cloud was stirred for approxi-

mately 15 seconds, it imparted a modest amount of angular momentum. To keep the cloud rotating, the researchers transferred the atoms to an extremely azimuthally symmetric trap.

To create a BEC cloud, the researchers used an evaporative cooling scheme that selectively removed the hottest atoms from the trap. By tailoring the evaporation surface to remove atoms with a high linear velocity and leave atoms with a high angular velocity, the researchers were able to create vortices in a single dimension. Specifically, the normal cloud rotated about the z-axis and the evaporation surface was a sheet in the x-y plane. This allowed the researchers to couple energy out of the cloud while keeping the angular momentum per particle constant.

“Much like an ice skater pulling in her arms to spin, our normal cloud inwardly shrank and began to rotate rapidly,” said Coddington.

When the researchers cooled the cloud below 100 nK, a condensate formed in the presence of a rotating normal cloud. In the smooth, non-rotating trap, the normal component and the condensate interacted strongly. In this environment, the researchers created condensates with a high vorticity (up to 130 vortices) and extremely high rotation (up to 96% of the trap frequency, the point at which the rotation would overpower the trap and cause the condensate to explode).

“Such high rotations in a condensate have never been achieved by other nucleation techniques,” said Coddington.

Although these vortices were too small to be seen in trap, the researchers released the cloud and allowed it to expand several times in size until the vortices were large enough to image. In this manner, the researchers observed the vortex-vortex interactions, which have been their most recent area of pursuit.

“Because of their mutual repulsion, vortices tended to order themselves in hexagonal Abrikosov lattices,” said Coddington. “By simply applying a sheer force to the condensate, however, we watched these lattices disappear and reform, melt into a liquid phase and, under extreme stress, form sheets of vortices.”

According to Coddington, these findings will help advance the understanding of quantum mechanics and the development of future nanotechnology devices.