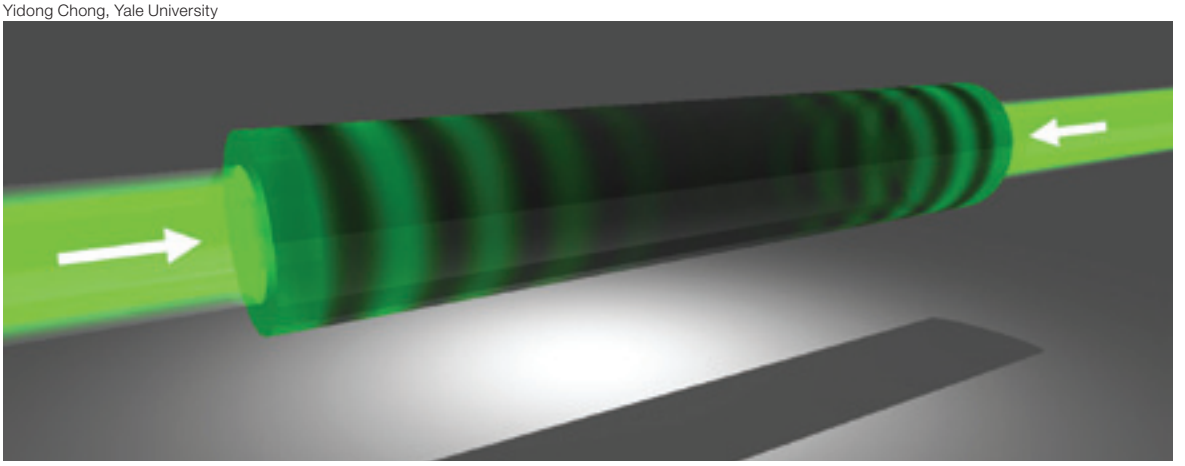
Yidong Chong, Yale University



Two counter-propagating laser beams impinge on a coherent perfect absorber or "time-reversed laser" made from silicon. The CPA can either perfectly absorb or strongly reflect laser light.

Time-Reversed "Anti-Laser" Controls Light Absorption

What's the exact opposite of a laser? The answer is not a riddle, but a real experiment in the controlled absorption of light.

Scientists at Yale University have created a time-reversed counterpart to laser emission, which they call a "coherent perfect absorber" or CPA (Science **331**, 889). In this proof-of-concept device, two coherent light beams enter a loss medium and cancel each other out—making a completely light-absorbing "anti-laser."

The team, led by OSA Fellow Hui Cao, split the beam coming from a tunable, cw Ti:sapphire laser and directed the two beam paths onto opposite sides of a silicon wafer approximately 110 µm thick. A phase delay in one of the beam paths controlled the relative phase of the twin beams, and an attenuator helped to compensate for imbalances in the beam splitters and other optical components.

The wafer functions as a Fabry-Pérot etalon—only with the amplifying medium replaced by a loss medium that dissipates the beam energy as heat. Inside the wafer, the opposing incident beams completely cancel each other out when they have the correct relative phase and amplitude. In other words, the device is a perfect absorber of specific wavelengths, as opposed to a laser, which converts the input energy to coherent light at certain wavelengths.

OSA Fellow A. Douglas Stone, who heads the applied physics department at Yale, developed the theory of the anti-laser last summer, and Cao and her team of experimentalists then built a working device.

Although the Yale team used near-infrared light between 990 and 1,010 nm in this experiment, Cao says that they could make the device work with shorter, visible wavelengths by using a thinner silicon wafer, or with longer, telecommunications-band wavelengths, which would be created by adding reflective coatings or introducing a dopant into the silicon.

One advantage of the Yale device is its relative simplicity compared with electromagnetically induced transparency, which is difficult to implement in solid-state materials, and highly engineered anti-reflective nanostructures. The setup functions as an absorptive interferometer for potential use as a modulator or optical switch.

— Patricia Daukantas

Microscopic Techniques Aid Understanding of Protein Transport

Researchers can now track proteins' movement through cells in three dimensions and study the responses of human immune cells to bacterial toxins, thanks to advances in optical microscopy reported at this week's annual meeting of the Biophysical Society in Baltimore, Md., U.S.A.

A team at the University of Texas (UT) Southwestern Medical Center demonstrated a multifocal-plane technique for visualizing 3-D dynamics within cells. According to UT biomedical engineer Sripad Ram, conventional microscopes have poor discrimination in the z-direction, or the vertical axis perpendicular to the focal plane.

In multifocal plane microscopy (MUM), as many as four focal planes, stacked up like a club sandwich, collect images at the same time. Beam splitters and mirrors send the signals from each focal plane to separate detectors. MUM

permits a faster frame rate of image acquisition than techniques involving adjustments of a single focal plane.

Ram and his UT collaborators used four focal planes, extending to a depth of about 7 µm, to track molecules tagged with quantum dots as they moved around in a 10-µm-thick live-cell monolayer. Ram is using the technique to study antibody trafficking within cells and other topics in immunology.

Also, Jesse Aaron and colleagues at Sandia National Laboratories demonstrated how a different super-resolution microscopy technique revealed subtle clues to the high infectiousness of the plague. Stochastic optical reconstruction microscopy (STORM) allowed the researchers to look at the receptor proteins on the outer surfaces of human immune cells and to measure their interactions with lipopolysaccharide toxins from infecting bacteria.

Patricia Daukantas

(Left) Jesse S. Aaron of Sandia National Laboratories, Albuquerque, N.M., U.S.A. (Right) Sripad Ram of the University of Texas Southwestern Medical Center in Dallas, Texas, U.S.A.

At 40-nm resolution—about an order of magnitude greater than that of optical fluorescence microscopes—STORM revealed that the receptors multiplied and clustered more for the toxins from *E. coli* bacteria than from *Y. pestis* (plague) germs. In other words, the human "innate" immune response works better against *E. coli* than the plague. Greater knowledge of this immune response may help scientists to prepare better defenses against biological weapons.

— *Patricia Daukantas*

Watching Molecular Machines Splice RNA

Multiwavelength single-molecule fluorescence microscopy, combined with genetic engineering and chemical biology techniques, allows unprecedented imaging of the splicing of RNA molecules by a complex molecular machine. A recent paper in *Science* describes how this unusual combination of methods allows researchers to study the assembly of a so-called "spliceosome" in real time (A.A. Hoskins et al., doi: 10.1126/science.1198830).

A number of processes within cells require molecules to self-assemble, perform a task, and then dissociate. We are still learning how these molecular machines work. For example, the areas of DNA that code for proteins are often interrupted by regions that do not; a molecular machine called the spliceosome cuts out the non-protein-coding regions of an RNA copy of the DNA and then splices the desired regions back together. "The splicing system is an extraordinarily complex piece of biology," explains Jeff Gelles at Brandeis, in whose lab much of the work took place.

Often, labeling proteins would involve purifying them, then attaching fluorescent dyes to them. However, that wouldn't work for the spliceosome. With more than 100 proteins involved, the researchers had to work with unpurified extracts from whole yeast cells. They used genetic engineering and chemical biological techniques to incorporate labels into specific protein components of the spliceosome. Lead author Aaron Hoskins developed the methodology to dye label the proteins in the complex mixture needed for spliceosome function.

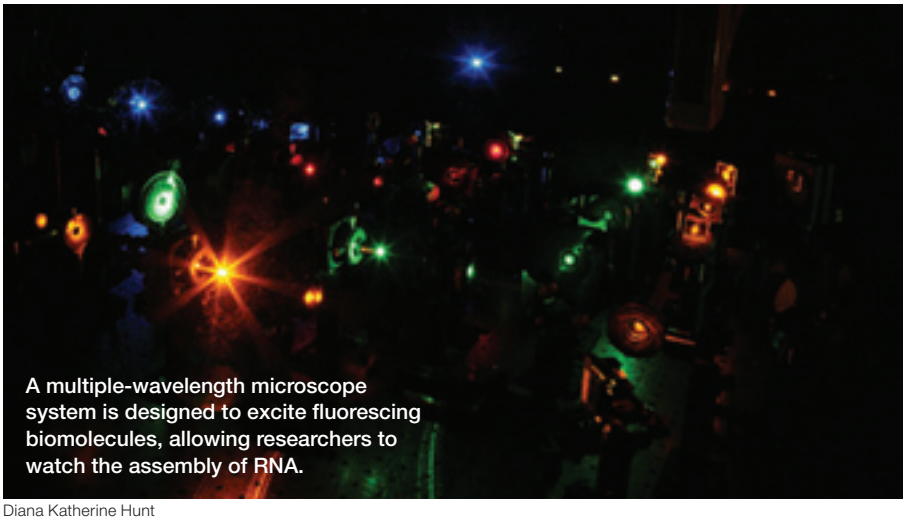
The multiwavelength single-molecule microscope then allowed the researchers to watch the splicing process in unprecedented detail. Three laser beams were combined and focused onto a small spot in the back aperture of the objective to excite the sample at multiple wavelengths simultaneously. The system uses tiny broadband mirrors, rather than wavelength-selective optics that reduce the bandwidth of the collected light. This increases the number of fluorescent photons gathered.

Models suggest that the spliceosome works in an organized, one-way fashion. However, while assembly is highly ordered, the researchers also found that it is also reversible. This discovery provides new insight into the processes responsible for selecting which pairs of sites splice.

"Understanding how these micromachines function inside the cell is important for many reasons," says Aaron A. Hoskins. Researchers may eventually be able to apply their knowledge of these processes to devise therapies to fix the splicing process in cases where it is not working properly.

"Even with these powerful techniques, it will take many years and people to apply them fully to this system," says Gelles. The combination of techniques can be used for analyzing other molecular machines as well.

—Yvonne Carts-Powell



A multiple-wavelength microscope system is designed to excite fluorescing biomolecules, allowing researchers to watch the assembly of RNA.

Diana Katherine Hunt

Researchers Control Inelastic Scattering Pathways in Graphene

Graphene—carbon in its two-dimensional form, just one atom thick—has attracted intense interest from researchers because of its potential applications in nanoscience. In another step toward understanding the material's properties, a team from Berkeley, Calif., U.S.A., has figured out how to control the quantum pathways of inelastic light scattering.

As reported in *Nature* (doi:10.1038/nature09866), Feng Wang and his colleagues directly observed quantum interference in graphene and figured out how to control the pathways by creating tiny ion-gel gates on doped graphene.

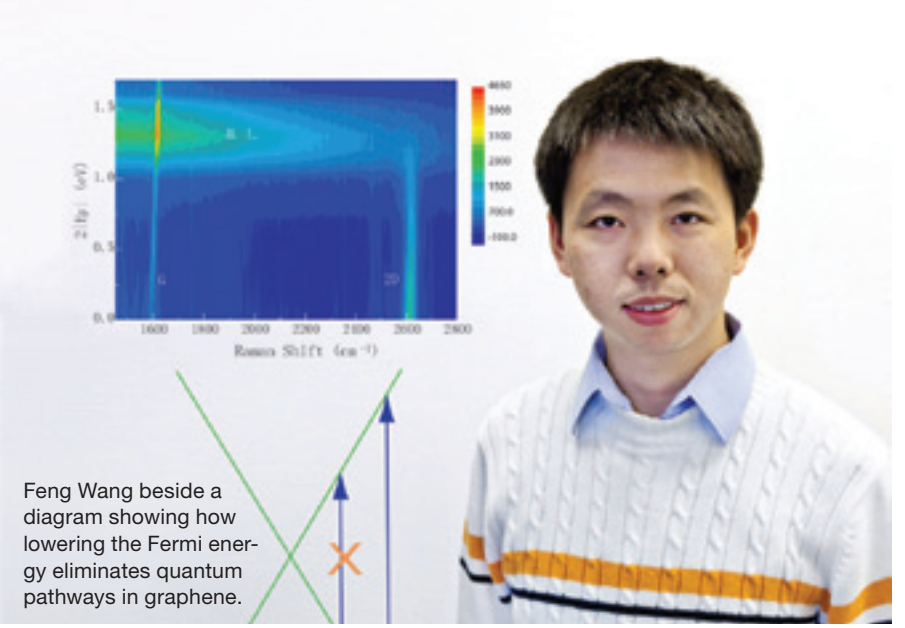
In conventional semiconductors, one cannot choose to block certain pathways, said Wang, an assistant professor of physics at the University of California at Berkeley. But the design of the experiment, led by Rachel A. Segalman of Lawrence Berkeley National Laboratory, allowed the researchers to do just that.

The scientists placed a sheet of graphene (originally grown on copper) onto a SiO_2 substrate and layered a thin coat of dielectric gel on top of that. They studied the inelastic light scattering from a 785-nm excitation laser while changing the gate voltages in the gel layer.

By raising the voltage, the researchers lowered the graphene's Fermi energy and thus blocked the quantum pathways of the higher-energy electrons in the material. That limited the number of pathways by which electrons could absorb the impinging near-infrared photons and emit lower-energy, Raman-scattered photons and phonons.

The experiments made it easy to see and quantify the effect of quantum interference on Raman scattering, according to Wang. When some of the pathways in the graphene layer were blocked, the Raman-scattered signal did not diminish, as originally expected, but instead grew much brighter.

Finally, the team found a broadband "hot luminescence" in the graphene that was unrelated to the Raman scattering. It is another form of inelastic light scattering within the doped graphene.



Feng Wang beside a diagram showing how lowering the Fermi energy eliminates quantum pathways in graphene.

Lawrence Berkeley National Laboratory

The research may not lead to immediate application in devices but is useful to scientists' understanding of graphene's behavior, Wang says.

—Patricia Daukantas

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