current in molecular wires with high efficiency, yet is remarkably resistant to the deleterious effects of vibronic coupling.

As reported in the September 21 issue of *Physical Review Letters* (DOI: 10.1103/ PhysRevLett.99.126802), Franco, Brumer, and Shapiro chose ω and 2ω far-off resonance, well below interband transition frequencies, thereby relying on Stark shifts to couple ground and excited electronic states adiabatically. The researchers used a model composed of a trans-polyacetylene (PA) oligomer, the ends of which are connected to macroscopic metallic leads. They employed the so-called tight-binding model (the full Hamiltonian of the system is approximated by the Hamiltonian of an isolated atom centered at each lattice point and the atomic orbitals are assumed to be very small at distances exceeding the lattice constant). The energy of the nuclei and electrons of the oligomer were represented with the well-known Su-Schrieffer-Heeger (SSH) Hamiltonian, which successfully reproduces the electronic structure and the dynamics of electronic excitations in PA. The electronic structure of the PA chain consists of 50 doubly occupied valence π orbitals and 50 empty π^* states separated by an energy gap of 1.3 eV. The leads were treated as rigid, semi-infinite chains. The researchers developed a Hamiltonian for the nanojunctions, treating each as a one-dimensional lattice.

The $\omega + 2\omega$ field was turned on and off smoothly during a 100-fs interval, and the amplitude, 6.1×10^{-3} V $^{-1}$, was kept constant for 400 fs. The photoinduced, electron-vibrational dynamics were followed within a mean-field, mixed quantum-classical approximation. For a relative pulse phase of $\phi_{2\omega}-2\phi_{\omega}= 0$ and averaging more than 1000 trajectories, the researchers found that the spectrum displayed considerable Stark shifts and narrowing of the energy gap, causing frequent crossings between ground and excited states in individual trajectories. In addition, charge bursts were deposited in the leads when the electron population was transferred from the valence to the conduction band. The researchers observed that a minimum in the energy gap was concomitant with the maximum in the field strength, but the Stark effect was only sufficiently strong to close the energy gap when the field had positive amplitudes. For $\phi_{2\omega}-2\phi_{\omega}=\pi/2$ the researchers found that the Stark shifts were equally strong for positive and negative field amplitudes, resulting in no net current; the direction of the current can therefore be controlled by the relative phase of the laser. Plotting the net rectification as a function of the laser phase, the researchers showed that up to 90% of the electrons can participate in the net current, the mechanism is resistant to decoherence effects, and the currents observed are phonon-assisted. Franco, Brumer, and Shapiro said that their prediction of ultrafast currents "could lead to the development of molecular switches that operate on a femtosecond timescale."

STEVEN TROHALAKI

Photonic Crystal Enhances Brightness of Quantum Dots

N. Ganesh, B.T. Cunningham, and colleagues at the University of Illinois, Urbana-Champaign (UIUC) have demonstrated enhanced fluorescence intensity by a factor of up to 108 by placing quantum dots on a photonic crystal. Potential applications include high-brightness light- emitting diodes, optical switches, and personalized, high-sensitivity biosensors.

"We are using photonic crystals in a new way," said Brian Cunningham, a UIUC professor of electrical and computer engineering and corresponding author of an article published in the August 2007 issue of *Nature Nanotechnology* (p. 515; DOI:10.1038/ nnano.2007.216). "We tune them to the specific wavelength of a laser used to stimulate the quantum dots, which couples the energy more efficiently and increases the brightness."

To enhance the fluorescence of quantum dots, Cunningham and colleagues create plastic sheets of photonic crystal using a

technique called replica molding. Then they fasten commercially available quantum dots to the surface of the plastic.

"We designed the photonic crystal to efficiently capture the light from an ultraviolet laser and to concentrate its intensity right within the surface where the quantum dots are located," said Cunningham, who also is affiliated with the university's Beckman Institute, the Micro and Nanotechnology Laboratory, and the Institute for Genomic Biology. "Enhanced absorption by the quantum dots is the first improvement we made."

Enhanced, directed emission from the quantum dots is the second improvement. Quantum dots normally give off light in all directions. However, because the researchers' quantum dots are sitting on a photonic crystal, the energy can be channeled in a preferred direction, such as toward a detector.

The group reported an enhancement of fluorescence intensity by a factor of up to 108 as compared to quantum dots on an unpatterned surface.

"The enhanced brightness makes it feasible to use photonic crystals and quantum dots in biosensing applications from detecting DNA and other biomolecules, to detecting cancer cells, spores, and viruses," Cunningham said. "More exotic applications, such as personalized medicine based on an individual's genetic profile, may also be possible."

Radio Wave Cooling Offers New Twist on Laser Cooling

Visible and ultraviolet laser light has been used for years to cool trapped atoms and, more recently, larger objects by reducing the extent of their thermal motion. Now, by applying a different form of radiation for a similar purpose, K.R. Brown and D.J. Wineland of the National Institute of Standards and Technology (NIST), J. Chiaverini of Los Alamos National Laboratory, and their colleagues have used radio waves to dampen the motion of a miniature mechanical oscillator containing more than a quadrillion atoms.

Described in the September 2007 issue of *Physical Review Letters* (DOI: 10.1103/PhysRevLett.99.137205), this demonstration of rf cooling of a relatively large object may offer a new tool for exploring the elusive boundary where the familiar rules of the everyday, macroscale world give way to the bizarre quantum behavior seen in the smallest particles of matter and light. There may be technology applications as well. The rf circuit could be made small enough for incorporation on a chip with tiny oscillators, which is currently the focus of intensive research for use in sensors to detect, for example, molecular forces.

The researchers used an rf circuit to cool a 200 mm × 14 mm × 1500 μm silicon cantilever vibrating at its natural resonant frequency of 7000 cycles/s (see Figure 1). The scientists cooled it from room temperature (~23°C) to –228°C. Other research groups have used optical techniques to chill microcantilevers to lower temperatures, but the rf technique may be more practical in some cases, because the equipment is smaller and easier to fabricate and integrate into cryogenic systems. By extending the rf method to higher frequencies at cryogenic temperatures, researchers hope eventually to cool a cantilever to its "ground state" near absolute zero (–273°C), where it would be essentially motionless and quantum behavior should emerge.

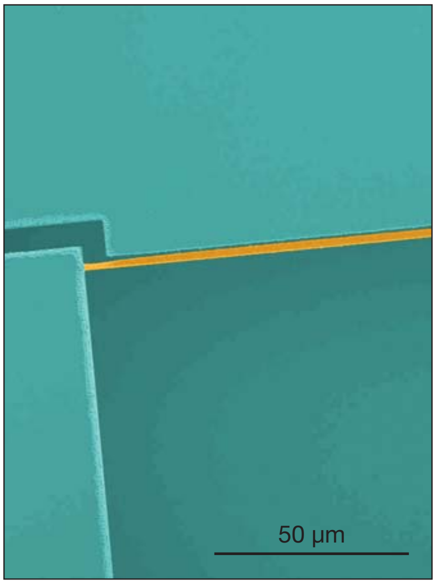

Figure 1. Radio waves are used to cool a silicon microcantilever, the narrow orange strip across the middle of the colorized micrograph. The cantilever, created by ion etching through a silicon wafer, lies parallel to a silicon radio-frequency electrode. Credit: J. Britton/ NIST.

In the NIST experiments, the cantilever's mechanical motion is reduced by the force created between two electrically charged plates, one of which is the cantilever, which store energy like electrical capacitors. In the absence of any movement, the force is stable, but in this case, it is modulated by the cantilever vibrations. The stored energy takes some time to change in response to the cantilever's movement, and this delay pushes the cantilever slightly out of synch, damping its motion.

Nanoblades Fabricated from Magnesium

F. Tang, G.-C. Wang, and colleagues at Rensselaer Polytechnic Institute have created a razor-like material called nanoblades, magnesium nanomaterials that could have applications in energy storage and fuel-cell technology. The discovery is detailed in the September 2007 issue of the *Journal of Nanoscience and Nanotechnology* (p. 3239; DOI: 10.1166/jnn.2007.665).

The sharp nanometer-scale surface is different from other nanomaterials created using oblique angle deposition, according to lead researcher Gwo-Ching Wang, professor and head of physics, applied physics, and astronomy at Rensselaer. The team's nearly two-dimensional structure changes traditional understanding of oblique angle deposition, which was previously thought to always create cylindrical structures like nanorods or nanosprings.

Unlike three-dimensional springs and rods, nanoblades are extremely thin, with very large surface areas. They also are spread out for a uniform nanomaterial, with 1–2 μm between each blade, according to Wang.

Oblique angle vapor deposition builds nanostructures by vaporizing a material and enabling the vaporized atoms to deposit on a surface at an angle. As the deposition angle changes, the structure of the material deposited on the surface also changes.

When the researchers deposited the magnesium straight onto a surface at 0°, the blades resembled a handful of cornflakes: flat, flakey structures overlapping one another. When the deposition angle was increased, the blade-like nature of these nanomaterials became apparent.

As the magnesium deposition angle increased, the structures first tilted away from the magnesium vapor source instead of inclining, as expected, toward the source. The blades then quickly curved upward to form nearly vertical structures resembling nanoscale razorblades.

The blades are also ultrathin. At a 75° angle, the nanoblades had a thickness of as little as 15 nm, a height of ~21 μm, and a width of a few hundred nanometers.

The researchers are now looking at ways to coat the magnesium nanoblades with metallic catalysts to trap and store hydrogen. The researchers monitored the blades as they were growing using a reflection high-energy electron diffraction technique to create a surface pole figure or image. The new technique, created at Rensselaer, is different from other diffraction techniques such as x-rays because it monitors the surface structure of the material as it grows. X-rays and other technologies measure the entire material,