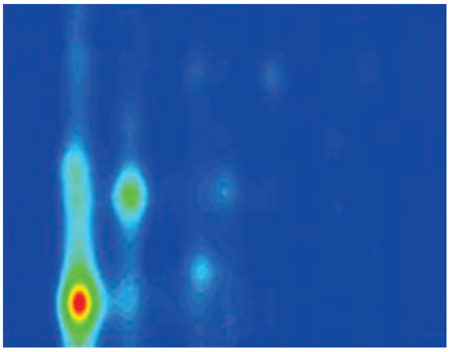
NANOPHOTONICS

Take your vitamins

Science **323,** 1319–1323 (2009)



Carbon nanotubes that reliably fluoresce brightly have been fabricated by a team of researchers from the University of Connecticut. Using a chemical that mimics a cofactor of vitamin B2, Sang-Yong Ju and others have shown that they can boost the photoluminescence yield of single-walled carbon nanotubes (SWNTs) to levels as high as 20%.

The optical — in particular, photoluminescent — properties of SWNTs are important for applications ranging from optoelectronics to biological imaging and sensing. Unfortunately, fluorescence quantum yields are usually low because of quenching that arises from defects, the presence of oxygen (which adsorbs into the nanotube sidewalls) and the fact that solution-suspended nanotubes tend to group together into bundles.

Ju *et al.* show that an analogue of a solvent known as flavin mononucleotide, or FC12, can solve these problems. It arranges itself around the SWNTs to form a helical wrapper and, unlike other surfactants, its organization is tight enough to exclude oxygen from the surface of the SWNTs. The result is a boost in the quantum luminescence yield; for aggregates of SWNTs the yield increases from 0.1–1.5% to 11%, and for an individual nanotube the maximum yield rises to 20%.

PHOTOVOLTAICS

New dimension for solar cells

Science **324,** 232–235 (2009)

Solar technology will be an important part of the world's future energy picture, and flexible solar cells are attracting increased attention as they promise to be more convenient and cheaper to deploy than conventional photovoltaic devices. Scientists at Konarka Technologies in the United States have taken this flexibility to another level, by designing organic photovoltaic cells that come in the shape of a wire and offer efficiencies of around 3%.

The Konarka team uses thin metal wires as the basis for their device, so that photogenerated electrical current can be carried over long distances. One wire, made of stainless steel, is coated with a photoactive layer made from a conducting polymer and fullerene derivative. The two phases form intertwined, worm-like domains that yield a high surface area and boost the efficiency of electron collection in the device. A second wire, which is coated with a silver film, serves as the counterelectrode and is wrapped around the first. Both electrodes are encased in a transparent polymer cladding, which focuses incoming light onto the photovoltaic layer even when it is completely shadowed by the counterelectrode. Compared with previous organic-based fibre photovoltaic devices, which are less than 1% efficient, this dual-wire design offers efficiencies ranging from 2.8 to 3.3%.

MICROSCOPY

Steady as she goes

Nano Lett. **9,** 1451–1456 (2009)

Atomic force microscopy (AFM) is a well-established technique, but unwanted mechanical drift between the probe tip and sample remains a critical and largely unaddressed issue. This drift can limit the stability of the AFM tip over a precise sample location and degrades registration, making it harder for the probe to return to a particular location.

Gavin King and colleagues have published a technique that addresses these challenges. By scattering focused laser beams off the apex of a commercial AFM tip, they show that it is possible to measure and control the three-dimensional position of the tip to within 40 pm. With this increased stability — which can be achieved with submilliwatt laser power — there is no need to scan rapidly while imaging, and the signal-to-noise ratio is improved by a factor of five.

Using a series of AFM images of transparent substrates, the authors demonstrate atomic-scale tip-to-sample stability (of the order of 100 pm) and registration over tens of minutes. Unlike previous efforts to improve AFM tip-to-sample control, the technique can be used in air at room temperature, and does not require a cryogenic or ultrahigh-vacuum environment.

QUANTUM OPTICS

Sensitive soul

Phys. Rev. Lett. **102,** 10301 (2009)

Sensitivity is the name of the game for gravitational-wave detectors. Scientists in Paris have studied how the quantum effects of radiation pressure — the mechanism by which light exerts pressure on any surface it comes into contact with — could affect the pursuit of these elusive gravitational waves.

Verlot and co-workers measure radiation-pressure-induced correlations between two optical beams sent into a moving mirror cavity. The first beam — an intense signal beam — causes the mirror to move by means of radiation pressure. A weaker second beam called the meter beam monitors the position fluctuations of the mirror. Because the intensity fluctuations of the signal are unchanged on reflection from the mirror, and the radiation pressure exerted by the weak beam is negligible, the intensity–phase correlations between the two reflected beams offer a direct measurement of radiation-pressure effects.

For the technique to work, losses and thermal variations have to be extremely low. The cavity, which uses a fused silica mirror, has a finesse of 330,000 and is operated in vacuum to increase its mechanical quality factor. The authors are able to detect weak correlations between the signal and meter beams at a quantum level, an advance that could benefit the fields of precision metrology and quantum optics.

BIOPHOTONICS

Pinning down proteins

Nano Lett. **9,** 1598–1603 (2009)

Researchers in the United States have devised a single-molecule technique that uses quantum dots to pinpoint the location of proteins bound to DNA. The method could be used to study DNA such as viral genomes or bacterial or mammalian genome fragments.

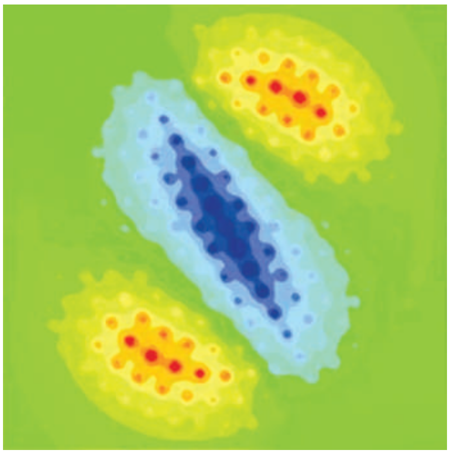
Transcription factors are one example of DNA-binding proteins, and the ability to identify their exact position and occupancy is important for gaining insights into cell processes such as gene expression and regulation. Ebenstein and co-workers perform a proof-of-principle experiment that uses far-field optics to probe a linear array of viral DNA strands to which RNA polymerase proteins are bound. The virus in question is T7, which infects most *Escherichia coli* strains.

Imaging is performed using fluorescence. In practice, four to six different transcription factors can be labelled with different quantum dots that emit in the visible and can be spectrally separated from one another. Strands of DNA are stretched out on glass slides in linear arrays, and a single light source is used to induce light emission. The researchers are able to pin down the position of multiple proteins on long stretches of DNA — spanning tens to hundreds of kilobases (1 kilobase is equal to 1,000 base pairs) — offering promise of a high-throughput analysis technique. Eighty-seven per cent of quantum dots are located to an accuracy of one kilobase.

IMAGING

In a squeeze

Phys. Rev. Lett. **102,** 103902 (2009)



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Complicated images can be pushed through tiny subwavelength holes without losing any of their fine detail, according to Mário Silveirinha and Nader Engheta. Their studies suggest that this is possible even when the hole has a diameter that is considerably smaller than the size of the image.

Overcoming diffraction typically involves metamaterials or plasmonic effects. In contrast, Silveirinha and Engheta suggest sampling an image 'pixel by pixel' using an array of parallel nanowires, then 'squeezing' the electric current associated with each pixel through a tiny hole, with essentially no reflection. In their proposal, a bundle of 217 metallic nanowires is squeezed through a tiny hole (about 2 μm in diameter) in an opaque metallic screen. To ensure that the energy associated with each image pixel is transmitted and not reflected, the screen and hole are embedded in a block of low permittivity — in this case, silicon carbide, which has a near-zero permittivity near the design wavelength of 10.3 μm.

Despite the subwavelength dimensions of the hole, even a complicated image can be reproduced accurately on the other side of the screen. Such an imaging system could potentially open the door to unprecedented manipulation of electromagnetic fields on the nanoscale.

OPTOFLUIDICS

Thin ice

Appl. Phys. Lett. **94,** 113901 (2009)

Optical tweezers are a well-known example of using light to control matter remotely. However, the idea of harnessing light to manipulate fluids rather particles — the principle of optofluidics — is also proving popular. Scientists have now shown that a moving laser spot focused onto a thin ice sheet can create fast-action microchannels useful for pushing other molecules along.

Weinert *et al.* scan an infrared laser beam across a micrometre-thick ice sheet. The ice melts at the laser spot and freezes behind it, and, as a result of the difference in specific volume, fluid flows inside the molten ice along the direction of the laser beam. The melting transition dynamics are such that ice can be pumped along freely defined patterns (in this case channels 25 μm wide and 3 μm deep) at velocities of up to 50 mm s^{-1}.

The authors demonstrate their mechanism by pumping fluorescent dye molecules across an ice–ice interface. By using an ice sheet as the channelling medium instead of water, the resulting thermoviscous pumping is three orders of magnitude faster. The diffusion limitation of ice means that dissolved molecules can be controlled without the need for pre-defined channels, valves or external pumps.

SILICON PHOTONICS

Round the bend

Opt. Express **17,** 4752–4757 (2009)

Low-loss silicon waveguides are critical for on-chip optical networks. But as with many technological challenges, the engineering approaches usually involve trade-offs: low losses but large bending radii (as with ridge waveguides), or small bending radii and higher losses (as with strip waveguides).

Now, scientists at Cornell and Harvard Universities have come up with efficient silicon waveguides that offer the best of both worlds. Their waveguides, based on a silicon-on-insulator wafer with a device layer of 500 nm and a 3-μm-thick buried oxide layer, are made in an etchless procedure whereby the silicon is never exposed to the etching plasma. In place of etching, Jaime Cardenas and colleagues choose a selective oxidation method, which results in ultra-smooth sidewalls with width variations of 0.3 nm and losses of just 0.3 dB cm^{-1} at a wavelength of 1.55 μm. The technique reduces bending losses to 0.007 dB per bend for a right-angled bend with a 50-μm bending radius.

LASER SCIENCE

Bumpy ride

Opt. Express **17,** 5058–5068 (2009)

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Lasers are useful for engineering glass surfaces that are difficult to mould or emboss. Carbon dioxide lasers are usually the tool of choice, but feature heights are limited to several micrometres because the absorption depth at their wavelength (around 10.6 μm) is small relative to the glass thickness.

Richard Grzybowski and colleagues have shown that by using different lasers, larger features are possible and bumps 100 μm or taller can be grown on glass. In place of a carbon dioxide laser, they use near-infrared lasers — an 810-nm pigtailed diode laser and a 1,550-nm fibre laser. Whereas light from a carbon dioxide laser couples to phonon oscillations in the glass, near-infrared laser light couples by an electronic absorption mechanism, meaning that the penetration depth can vary from several tens of micrometres to several millimetres.

The resulting laser-induced bump can reach 10–13% of the overall glass thickness and depends on the glass base composition. In the case of doped borosilicate glasses, the swelling is reversible, and the bump height can be increased or decreased depending on whether consecutive laser pulses have higher or lower energy than previous ones. Grzybowski *et al.* suggest that this approach to glass swelling could be used to make tightly packed arrays of tiny lenses with varying numerical apertures, or to perform very precise alignment of micrometre-sized components.