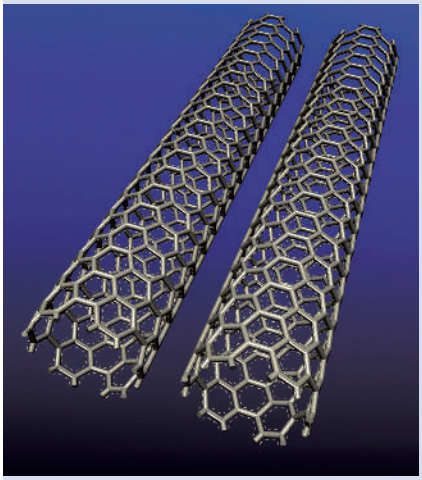
CARBON NANOTUBES

Feeling the heat



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Nature Nanotech. **2,** 33–38 (2007)

Carbon nanotubes — a single layer of graphite rolled into a cylinder — have been at the centre of a mini-revolution during the past 15 years. Their unique properties have seen them put forward for use in everything from super-strong materials to nano-electronics. Although light emission from semiconducting carbon nanotubes was observed some time ago, it was not clear whether this was also possible in metallic tubes — until now. David Mann and his colleagues have shown electroluminescence from so-called quasi-metallic single-walled carbon nanotubes. All that is needed to generate light is to apply a small voltage (approximately 1.4 V) across suspended tubes, each 2–4 nm in diameter and 2–10 μm long. Light is generated both in the near infrared and at visible wavelengths. The authors suggest that self-heating is probably the cause of this unexpected result — electrons are driven into energy states more associated with temperatures as high as 1,200 K, from where they can decay radiatively — so-called thermal emission. This means that such luminescence could provide a new technique for investigating the physics behind these invaluable structures.

SLOW LIGHT

Perfectly slow

Opt. Express **15,** 219–226 (2007)

The extent of interest in slowing light is highlighted by the range of approaches taken so far: photonic crystals, microring resonators and various kinds of nonlinear effects. Photonic crystals in particular offer the large bandwidth crucial for telecommunications; however, devices fabricated to date have suffered from dispersion. Now, a collaboration of researchers from the UK, the Netherlands, the USA and Israel has looked carefully at the design of these waveguides to try and identify how best to achieve low-dispersive and wide-bandwidth slow light. Their solution — select a waveguide mode at a frequency far from the photonic-bandgap edge. To validate their ideas, the multinational team created a waveguide based on a triangular-lattice photonic crystal with two rows of holes missing, producing a line defect. Passing laser light with a wavelength of 1,509 nm along the waveguide, they demonstrate slow light with a delay of 12 ps and a bandwidth of 2.5 THz. An important figure of merit, the product of these two parameters, is an order of magnitude larger than any design reported so far.

OPTICAL TWEEZERS

A finer point

Phys. Rev. A **75,** 013406 (2007)

Sharply focused laser light can produce a force large enough to manipulate single atoms and molecules. The question is how best to construct these so-called optical tweezers. Yvan Sortais and colleagues at the Laboratoire Charles Fabry de l'Insitut d'Optique in France have come up with an elegant and convenient optical system for getting focused light in and weak fluorescent signals out of the vacuum chambers necessary in these experiments. The requirements are stringent: the final laser spot must be diffraction-limited to make it as small as possible, and this condition needs to be met over a broad spectral range to work at both the laser and the atomic fluorescence wavelengths. The team's solution is to place an aspheric lens in the vacuum chamber and a series of spherical lenses outside. The system exhibited diffraction-limited resolution at wavelengths between 700 nm and 880 nm and over a transverse distance of 50 μm. To further prove the potential of their concept, Sortais *et al.* resolved two rubidium atoms trapped only 2.2 μm apart by the optical tweezers. The ability to trap and control single atoms with such resolution provides an essential tool for many fields of research; atomic physics and quantum optics, to name just two.

PLASMON LITHOGRAPHY

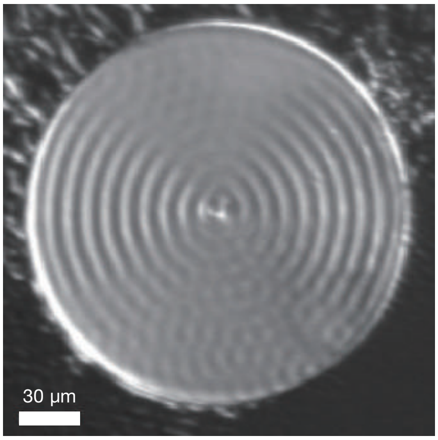
Route to bumpy terrain

Appl. Phys. Lett. **90,** 044105 (2007)

Surface-plasmon polaritons (SPPs) offer us a cornucopia of fascinating and useful effects. The latest of these is the ability to pattern thin films in intricate ways. Lars Röntzsch and colleagues describe how SPP waves can be used to control the thickness of polymethyl methacrylate (PMMA) layers deposited on metals, suggesting a new way to pattern thin films.

The underlying principle is one of kinetics. In micro- and nano-sized structures, such as thin films, capillary effects are particularly important because of their large surface-to-volume ratio. Under the correct conditions, variations in temperature across the material can induce a 'flow' of that material — a process known as thermocapillarity. If this temperature gradient is periodic in space, the effect can lead to long-range ordered patterns on the surface of the material.

By exciting plasmons at the PMMA–metal interface, the authors induce just such temperature gradients, a surface-temperature difference of 5 K: damping of the SPP waves leads to position-dependent power losses and local heating of the PMMA film. The resulting flow of PMMA material results in periodic ripples, as illustrated below, that are well described by kinetic simulations. By changing the geometry of the metal pad to a curved or angled interface, more exotic patterns such as rings and hillocks are produced. This SPP lithography could be particularly useful in shaping polymer films.



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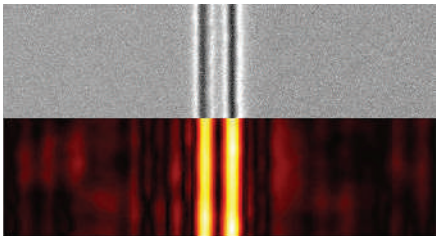
SUPERLENSES

Far and away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Nano Lett. doi: 10.1021/nl062635n; 2007

Superlensing — imaging beyond the diffraction limit — could be achieved in the far-field and without the need for time-consuming scanning, according to recent research. Information about an object is stored in reflected light, either as propagating waves or decaying evanescent waves. Although propagating waves can be collected by standard lenses, move too far from the object (the far-field) and the evanescent information is lost, limiting the resolution of the image to about half the wavelength. Superlenses amplify evanescent waves making subwavelength resolution imaging possible. Now, Xiang Zhang and colleagues at the University of California at Berkeley have extended this important concept. Using surface plasmons on a silver surface, the team converts evanescent waves to propagating waves, allowing all the information to be collected by a standard optical system. This is experimentally verified by imaging two 50-nm strips of chromium separated by 70 nm, with laser light at a wavelength of 377 nm. This approach could prove to be real competition for near-field optical microscopy, which involves scanning a probe over the object, limiting where it can be applied and the speed at which images are generated.

QUANTUM INFORMATION

More entanglement

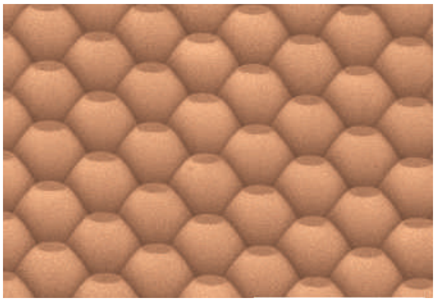
Phys. Rev. Lett. **98,** 010502 (2007)

In the world of quantum information, photons are important for transmitting data whereas atoms are useful for storing that information. Many believe that the ideal network would contain confined entangled atoms that communicate through optical channels. The question is, just how entangled can those atoms get? Researchers from Spain and Germany now provide some interesting insights into this question.

Any two atoms can become entangled by collecting the photons they give off — the entanglement arises owing to interference in the measurement process. Current dogma suggests that the degree of entanglement is fundamentally limited to one entanglement bit or 'ebit'. Lamata and colleagues now show that it is possible to generate an arbitrary amount of entanglement using a device known as an entangling two-photon detector (ETPD). The detector clicks whenever two photons arrive at the same time and their momenta satisfy a particular constraint. By analysing the results from the ETPD measurements the authors prove mathematically that two atoms can be entangled with any number of ebits. In practice, obtaining large numbers of ebits might be tricky, nevertheless, interesting tests of quantum physics or entanglement of whole atomic clouds could be performed.

LIQUID-CRYSTAL DISPLAYS

Light but bright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[1]*Jpn J. Appl. Phys.* **46,** 194–199 (2007)
[2]*Jpn J. Appl. Phys.* **46,** 182–186 (2007)

Liquid-crystal displays are now common place in personal computers, mobile products and televisions as well as many other items. However, as LCDs are passive optical components, they do not create light and require a backlight. A better backlight leads to higher-quality, brighter images and lower power consumption. In order to make LCDs lighter and brighter, Katsuya Fujisawa and colleagues in Japan are investigating placing the light source at the edge of the display[1]. The light is guided behind the LCD by a thin plate and then redirected upwards by a film patterned with fine lenses. By changing the shape of the fine lenses and their spacing, the emission properties of the display can be controlled. With this technique, they report extraction efficiencies at least 10% higher than in a conventional backlit unit.

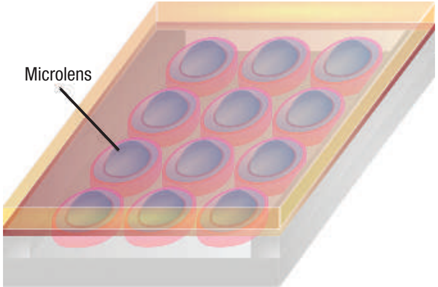
Another approach, taken by a group of Chinese researchers at the National Chiao Tung University in Taiwan, China, is to integrate organic light-emitting diodes with the LCD to create a so-called emi-flective display[2]. With no air gap inbetween the emi-flective (emissive and reflective) components, this device eliminates undesired reflection and offers lighter weight (<90%), thinner thickness (<40%), and lower power consumption (<2%, under sunlight) in comparison with conventional LCDs.

LIQUID LENSES

Varifocals

Adv. Mater. **19,** 401–405 (2007)

The curved surface of a liquid drop can bend rays of light, just like a glass lens. The beauty of such liquid lenses is that their shape can be altered, providing a way of adapting their focal length. Liang Dong and co-workers at the University of Wisconsin-Madison in the USA are developing a focus-control technique that, unlike approaches investigated so far, doesn't require bulky external power supplies. They use a material known as a hydrogel that expands and contracts with temperature, swelling by as much as ten times as the temperature decreases below a critical point. The water-based lenses, a few millimetres across, were shaped by 750-µm-deep hydrogel channels; rectangular channels produced a cylindrical lens, and a grid of circles created a spherical microlens array. A small heater on the back of the device increases the temperature from 21 °C to 43 °C, allowing control over the meniscus shape and hence tuning the focus length of the lens. In the case of the cylindrical microlens, the shape changed from convex to concave at about 34 °C. By simplifying the way liquid lenses are controlled, these components could be readily integrated into lab-on-a-chip systems.



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