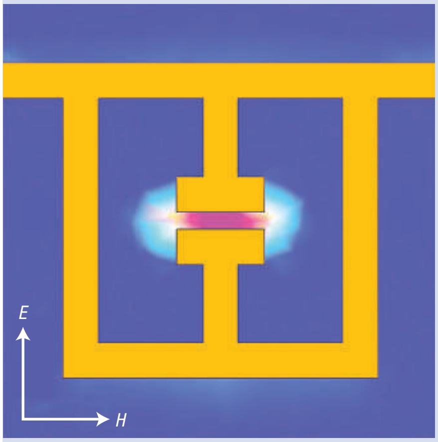
METAMATERIALS

Filling the THz gap



Nature **444,** 597–600 (2006)

Terahertz (THz) radiation research has focused on generation and detection rather than actively controlling and manipulating THz waves, which is made difficult owing to the lack of materials that respond to them. Now studies from Chen and colleagues show that metamaterials can provide new levels of control.

Their device consists of an array of tiny gold resonator elements (the metamaterial) sitting on a semiconductor substrate. The elements are 'split-ring resonators', pairs of concentric metallic rings with gaps that prevent current from circulating through them. Because the rings act both as capacitors and inductors, the presence of the gaps creates a resonant response.

Chen and co-workers engineer their metamaterial structures so that this resonance occurs when THz-frequency radiation is shone on the device. By applying an electrical voltage to the semiconductor, they can control the resonance at will — and therefore the amount of radiation allowed to pass through. The authors demonstrate an on–off transmission ratio of 0.5, which is 10 times better than that offered by conventional devices in this frequency range. But more importantly, they reveal a new way of actively controlling THz light.

ALL-FIBRE SWITCH

Splice device

Opt. Lett. (Doc ID: 76523) (2006)

Fibre lasers are difficult to modulate as they can't be switched on and off like semiconductor diode lasers. Now, researchers from Acreo in Stockholm, Sweden, have created a fibre-based device capable of rotating the polarization of light, and thus modulating a laser, at a frequency of up to 10 kHz.

The key to the device produced by Knape and Margulis is two metal wires running along the core of an optical fibre. Passing current along these applies a uniform mechanical stress to the fibre, providing sufficient birefringence to rotate vertically polarized light to the horizontal. A 125-μm diameter fibre was drawn with two 28-μm air columns near the centre, which were filled with molten BiSn or AuSn to form the 10-cm long alloy wires. The optical loss in the device was as low as 0.2 dB at a wavelength of 1.55 μm, and switch voltage pulses of approximately 1 kV were applied for 100 hours without any significant fatigue. The all-fibre switches can be easily spliced into an optical-fibre system, offering a compact and simple method of modulating fibre lasers.

LASER-DRIVEN ACCELERATORS

Protons get intense

Nature Phys. **3,** 58–62 (2007)

High-powered lasers now offer a convenient approach to accelerating ions to high energies. Laser-accelerated protons are particularly interesting, because they could potentially treat deep-seated cancers in the body. The key is to produce many protons with a high enough energy. Studies from Robson and colleagues give us new insights into how this might be possible.

The idea behind laser-driven proton acceleration is relatively simple: shine a very intense laser light onto a thin metal foil. Hydrogenated contamination layers on the surface of the foil provide the protons. By ionizing the foil's atoms and accelerating its electrons, the laser causes charge separation and a strong field gradient. This field then accelerates the protons to high energies — so far up to 60 MeV. But for targeting hidden cancers, intense proton beams of around 200 MeV are required.

The researchers study how proton energies and yields from aluminium targets scale with laser intensity (up to 6×10^{20} W cm^{-2}), energy (up to 400 J) and pulse duration (up to 10 ps). Surprisingly, peak proton energy increases with laser intensity more slowly than expected, suggesting that current theoretical models must be changed to explain the ion acceleration at high laser intensities. The team finds that 200-MeV proton beams should be possible, although they will be trickier to obtain than expected.

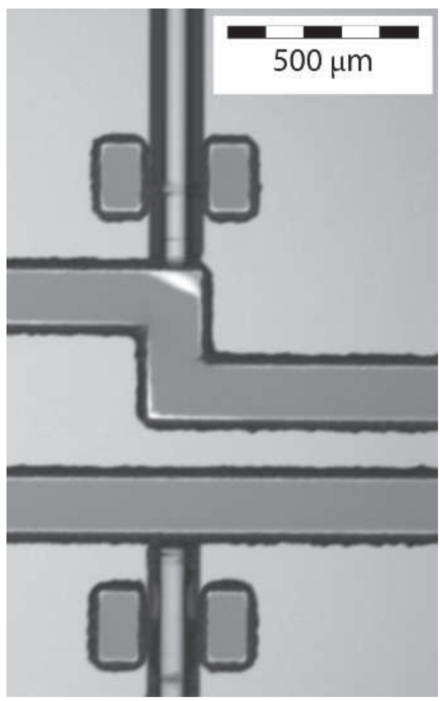
MICROFLUIDICS

Feel the flow

Appl. Phys. Lett. **89,** 224101 (2006)

Lasers offer a particularly sensitive means of chemical and biological sensing. Their output properties are altered by very small changes within the optical cavity, such as fluctuations in the refractive index or optical absorption. Now, Galas and colleagues have integrated a laser onto a microfluidic chip and investigated the potential of the device as a chemical detector.

Their structure consists of a 600-μm long laser cavity sandwiched between two mirrors made from the cleaved ends of two optical fibres, each coated in gold. Two microchannels run between these mirrors. The first carries the laser gain material: in this case, a fluorescent dye, rhodamine 6G, dissolved in ethanol. The dye flows through the optical cavity at a speed of 5 mm s^{-1} and lases at a wavelength of 570 nm, when optically pumped. The team monitored changes in the output power of the microfluidic laser as an analyte flows through the second channel. In this way, concentrations down to 10^{-6} mol l^{-1} can be detected. Its small size, low cost and simplicity give this type of device key advantages over alternative techniques.



OPTICAL CLOCKS

Atoms make time fly

GETTY

Science **314,** 1430–1433 (2006)

Optical transitions of electrons between atomic energy states provide a means of accurately defining time. Now, scientists at the National Institute of Standards and Technology in Colorado, USA have reached a higher level of precision using an ensemble of neutral atoms. The accuracy of an optical clock is determined by the spectral width of the atomic absorption spectrum, as characterized by the *Q* factor — the ratio of the light frequency to the resonance linewidth. A fundamental limit is imposed by the interaction of the atoms with their surroundings, disrupting the exact timing of the transition. In the set up used by Boyd *et al.* the atoms are trapped in an optical lattice specially engineered to reduce external influences, trapping approximately 10,000 cold strontium atoms. The ensemble exhibits a peak in its absorption spectrum at a frequency of 4.3×10^{14} Hz (a wavelength of 698 nm) and a linewidth of 1.8 Hz. This represents a *Q* factor of 2.4×10^{14} — the highest value ever recorded in coherent spectroscopy. The impressive spectral resolution could prove a boon to frequency metrology.

NONLINEAR OPTICS

X-coherence

Phys. Rev. Lett. **97,** 243903 (2006)

Coherence is important in optics. It is traditionally separated into two concepts: spatial coherence, which allows two points on a field to interfere, and temporal coherence, which permits a field to interfere with a delayed version of itself. Research by Jedrkiewicz and co-workers now demonstrates that, for some types of nonlinear light at least, this separable description of coherence is not valid.

In their experiment, nonlinear light is created by so-called parametric super-fluorescence generation from the crystal beta barium borate. This signal is then analysed, for the first time, over the entire space–time domain. The results show that coherence is neither spatial nor temporal, but skewed along spatiotemporal trajectories in an X-shape — two points in the field are correlated with each other only for certain combinations of temporal delay and spatial separation. The importance of this work is that it is not just limited to optics, but could be equally applicable to other types of nonlinear waves, from Bose–Einstein condensates to plasma and matter waves.

CAVITY QED

In the right place

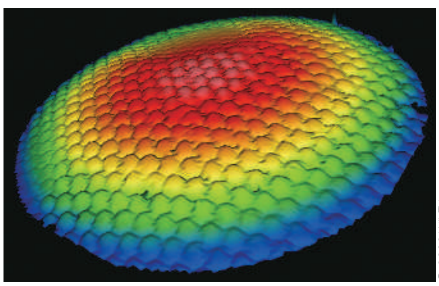
Nano Lett. **6,** 2920–2924 (2006)

Cavity quantum electrodynamics (QED) uses optical resonators to enhance light–matter interactions. However, existing designs of cavity systems that exploit these effects are impractical for real applications, owing to their fragility and incompatibility with electrical injection. In addition, aligning a solid-state light source with such a cavity has so far proved problematic.

An approach that isn't afflicted by these limitations has been taken by Muller and colleagues from the University of Texas, USA. In their system, bottom and top mirrors provide vertical light confinement and mesas etched before the growth of the top mirror provide lateral confinement. The light source, quantum dots, is in the mesa and so is self-aligned to the cavity. With these structures, the team is able to demonstrate a cavity QED effect — the enhancement of the spontaneous emission rate. This system is also particularly attractive for boosting the performance of quantum-dot lasers.

MICROLENS ARRAYS

Wrinkle to be proud of



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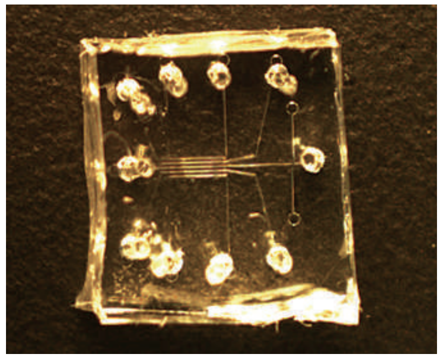
Adv. Mater. **18,** 3238–3242 (2006)

Existing microlens-array fabrication techniques are often either expensive or time consuming. Now, Chan and Crosby from the University of Massachusetts in the USA have introduced an approach that not only offers rapid and cheap manufacture, but also enables easy control over the lens shape and is versatile enough for use on non-planar surfaces.

The key to their technique is surface wrinkling. Oxidation of specific regions of a polymer film creates elastic tension on the surface, leading to wrinkle formation. Varying the geometric shape and material properties of the wrinkled regions allows control of the size and the arrangement of the microlenses. The team demonstrates the flexibility of their technique by constructing a microlens array on a hemispherical surface — creating a compound lens, similar to a fly's eye. The present microlenses are 5 μm in height and 60 μm across; however the authors predict that the general concept can be extended to enable surface wrinkles to be used to generate nanoscale structures.

IMAGING AND SENSING

Nanosensor solution



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Adv. Mater. **19,** 61–66 (2006)

By combining their knowledge of nanomaterials and optics, scientists from the USA have built an ultracompact optical sensor that is able to interrogate liquid solutions with subpicolitre volumes.

The device, developed by researchers at the Lawrence Berkeley National Laboratory, is based on the marriage of subwavelength nanowire technology and spectroscopy. The sensor uses a nanoribbon structure made of single-crystalline tin oxide to implement efficient waveguiding across channels that have a chemical analyte flowing through them. By performing absorbance, fluorescence and surface-enhanced Raman spectroscopy, the researchers are able to carry out measurements of the sample's refractive index and concentration.

On optical pumping, the emission intensity from the nanoribbon waveguide is attenuated by the absorbance of the analyte species. To enhance the evanescent field around the nanoribbon and thereby enhance the Raman signal, the team add 50-nm silver nanocubes to the waveguide surface. The result is an enhanced level of sensitivity and a high degree of chemical specificity that would not otherwise be possible. The team expects that its research could lead to the design of advanced compact optical sensors.