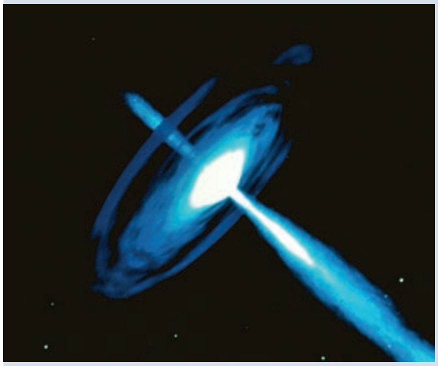
OPTICAL FIBRES

Lab black hole



GETTY

Science **319,** 1367–1370 (2008)

According to quantum physics, a black hole is not completely black, but radiates with an effective 'Hawking temperature'. The Hawking temperature of a black hole is typically well below the cosmic background radiation, so it is unlikely to ever be observed. However, Ulf Leonhardt and colleagues at the University of St Andrews in Scotland and the Max Planck Research Group of Optics in Germany have now developed a laboratory analogue using a microstructured optical fibre.

They created 70-fs non-dispersive pulses inside a commercial microstructured fibre. Each pulse causes a change in the refractive index, which moves with the pulse, as a result of the Kerr effect. The pulse was followed by continuous-wave probe light with a higher group velocity and a different frequency. The Kerr index change slows down the probe light as it approaches the pulse. Thus the trailing end of the pulse establishes a white-hole 'horizon', into which light cannot enter. For probe light slower than the pulse, the front end creates a black-hole horizon, from which nothing can escape. The resulting spectra matched well with the theory of light propagation in the presence of horizons.

The researchers further hypothesized on the use of a set of probe modes instead of a single probe. By analysing the Doppler formula that relates different frames of reference, the researchers show that the pulse in the fibre can spontaneously create photon pairs, providing a laboratory analogue of Hawking radiation at a temperature of 10^3 K.

ALL-OPTICAL CONTROL

Faster switching

Opt. Lett. Doc. ID: 91394 (2008)

All-optical signal processing is important for next-generation photonic circuits and optical communications. So far, researchers have looked into using nonlinear bistable materials as the basis for all-optical switches, but switching response times of such devices have not been investigated thoroughly. Changjun Min and colleagues report an all-optical switch that is based on a metallic subwavelength grating structure containing nonlinear optical materials. By using a metal–dielectric (gold and silicon dioxide) composite that has a large third-order nonlinear susceptibility, they demonstrate ultrafast response properties with switching times of the order of picoseconds.

The all-optical switch consists of a silver subwavelength grating coated with the composite nonlinear layer. Signal and pump beams both illuminate the nonlinear side of the structure, and the dependence of the intensity of the transmitted signal light on the pump light intensity exhibits bistable behaviour and thus a switching effect. The nonlinear effect is enhanced further, thanks to the excitation of surface plasmons at the metallic nanostructured grating. As a result, the pump light intensity needed to perform switching is less than 12 MW cm^{-2}. This is lower than for other such structures reported, and can be easily supplied using lasers that could be combined with the switch to create a compact, integrated device.

PLASMONIC SENSING

What a nerve

Opt. Lett. Doc. ID: 91210 (2008)

Researchers in Korea and the USA have used a surface-plasmon resonance to optically detect activity in rat nerves. The approach offers a non-invasive, label-free way of probing neural signals.

Typically, an investigation of extracellular nerve signals involves applying some form of electrical stimulation to the nerve. However, the recorded signals often contain artefacts arising from the stimulating pulse. Optical recording, on the other hand, does not suffer from this drawback.

Usually fluorescent dyes are used to record the signals; however, these dyes are expensive, toxic and involve lengthy labelling processes. Shin Ae Kim and colleagues get round these problems by turning to surface-plasmon resonances. When an electrical impulse travels along a nerve, it causes physical changes that result in a change of refractive index. The corresponding rapid changes in the optical properties of the nerve can be picked up through the effect on a surface-plasmon resonance. Kim *et al.* demonstrate their approach in sciatic rat nerves that are adhered to a gold plasmonic surface in a recording device. Through simultaneous measurements of electrical and surface-plasmon-resonance signals, the optical responses are proven to be linked to *in vitro* neural activity. The next step is to apply the technique to *in vivo* settings.

OPTICAL CAVITIES

See the light

Appl. Phys. Lett. **92,** 111111 (2008)

Tiny cavities capable of confining light on a scale comparable to the optical wavelength have opened up an entirely new branch of physics — cavity quantum electrodynamics. A team of French scientists have now used scanning near-field optical microscopy (SNOM) to take a peek at what is going on inside these cavities when they trap light.

Loic Lalouat and co-workers used a photonic-crystal-based cavity fabricated in a ridge waveguide on a silicon-on-insulator substrate. The volume of the cavity is just 5.5×10^{-14} cm^3 and the quality factor, a measure of how long the cavity traps light, is 41,000. A tunable laser was used to couple light into the ridge waveguide. The trapped mode was mapped using SNOM in two distinct modes: the conventional collection-scanning mode and the recently proposed interaction-scanning mode. It was found that whereas the collection-scanning approach detected the entire electromagnetic field around the cavity, interaction scanning enabled near-field imaging of just the resonant mode, at a wavelength of approximately 1,558 nm. This provides an insight into the way light is confined in these very useful structures.

Another observation of the study was that the presence of the SNOM probe did not drastically alter the cavity's light-confining abilities. This has led the researchers to suggest that the technique may offer a way of mechanically controlling the confined electromagnetic fields.

LIGHT-EMITTING DIODES

A quicker way out

Adv. Mater. **20,** 1253–1257 (2008)

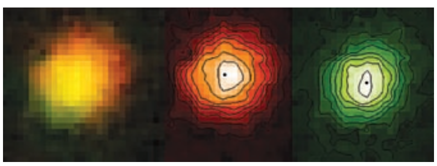
With LEDs rapidly becoming the first choice in lighting and displays applications, researchers are keen to identify anything that has the potential to improve their performance. One candidate, investigated by Min-Ki Kwon and colleagues at the Gwangju Institute of Science and Technology in Korea, is the use of surface plasmons.

Interest in the semiconductor GaN is largely due to its large bandgap, which enables the generation of blue light. Surface plasmons have been used to enhance the emission from GaN-based LEDs before, but now the principle has been extended to take advantage of coupling between quantum wells and surface plasmons. Energy from an exciton in a quantum well can be transferred to a surface plasmon in a metal nanostructure if the surface plasmon has a similar energy. The roughness of the metal means that the high-momentum surface plasmons scatter and lose momentum, and can therefore couple to light.

The LEDs were fabricated by depositing silver nanoparticles on an n-doped GaN layer. An InGaN multiple-quantum-well active region was grown on top of this and then a final p-doped GaN layer. The emission from the device was compared to a similar device without the silver nanoparticles. Time-resolved experiments indicated that the exciton lifetime was reduced from 140 ps to 80 ps at room temperature with the addition of the nanoparticles, an indication of the improvement in internal efficiency. The overall optical output of the LED was improved by 32.2% owing to the coupling between the quantum well and the surface plasmons.

IMAGING AND SENSING

Nanoscale probing



Proc. Natl Acad. Sci. **105,** 3298–3303 (2008)

By taking advantage of the brightness, photostability and multicoloured light emission of bioconjugated nanoparticle probes, scientists from the USA have come up with a simple way to both image nanoscale biomolecular structures and to detect single molecules. Their technique uses only standard fluorescence microscopes and inexpensive digital colour cameras.

In the approach developed by Amit Agrawal and co-workers, green and red nanoparticles are attached to two binding sites on a single target molecule, thus allowing dual-colour imaging at nanometre precision. The researchers fit the fluorescent intensity profiles to a two-dimensional gaussian function to determine the centre of individual nanoparticles, so-called colocalization. This is achieved in a quick and automated way with the aid of a statistical-analysis method borrowed from astrophysics. The analysis yields information about the number of detected target molecules and their size. The team's previous method used a confocal laser beam to monitor flow in a capillary channel, but this was slow (one molecule at a time) and involved only a few nanolitres of sample. In contrast the new approach leads to fast, parallel detection in much larger sample volumes. The researchers foresee that the application of their technique could be extended to structural mapping of biomolecular complexes and assemblies.

FREE-ELECTRON LASERS

Ring generation

Phys. Rev. Lett. **100,** 104801 (2008)

Giovanni De Ninno and a team of international collaborators have now demonstrated an alternative method for coherent harmonic generation of intense tunable short-pulse radiation in the deep UV to X-ray wavelength range. The approach may have advantages for experiments probing ultrafast processes.

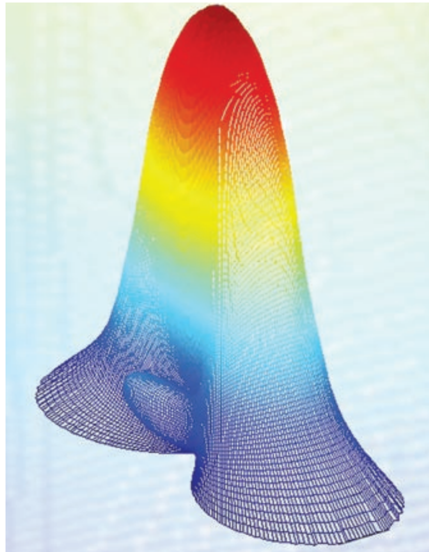
Coherent harmonic generation is achieved through interaction between a laser and a relativistic electron beam, generated in bunches with a period equal to that of the laser seed pulse. Light emission at the harmonics of the seed pulse is enhanced by interactions with the coherent electron bunches. Usually an external laser is coupled with a linear accelerator, but Ninno *et al.* have shown that efficient coherent harmonic generation can be obtained using a storage-ring oscillator free-electron laser.

In the storage-ring free-electron-laser configuration, light emitted by the electrons as they pass through undulators is stored in an optical cavity and amplified during successive interactions with the electron beam until lasing occurs. The authors compared results from the Duke and Elettra storage-ring free-electron lasers with three-dimensional numerical simulations, using the code GINGER, which solves the coupled system of particles and fields based on the Newton–Lorentz and Maxwell equations. The researchers found good agreement between experiments and simulations.

Because the particle density in the bunch is inhomogeneous, the temporal radiation is naturally characterized by very short spikes in which most of the energy is concentrated. This subpicosecond temporal structure may be exploited for investigating ultrafast phenomena.

PLASMONICS

Nanopatch lasers



IEEE J. Quant. Electron. **44,** 435–447 (2008)

To devise coherent light sources suitable for future on-chip optical interconnects and dense photonic very-large-scale-integration circuits, the challenge is to obtain an ultrasmall device that has a high-quality output beam shape. In pursuit of this, researchers from Cornell University in the USA have proposed and analysed a family of nanoscale semiconductor cavities for electrically pumped surface-emitting semiconductor lasers that operate at wavelengths of 1.0–1.6 μm.

The devices demonstrated by Christina Manolatou and Farhan Rana — called nanopatch lasers — consisted of a bulk semiconductor gain medium in the form of a p-i-n heterostructure sandwiched by silver layers. The radii of the cavities were in the range of 100–300 nm and the heights of the dielectric part of the cavities were between 100 nm and 250 nm — basically a nanoscale version of the micropatch antennas used at microwave and radio frequencies. Surface plasmons are used to confine the optical mode in the cavities and to shape the output beam to realize single-lobe far-field output radiation patterns with narrow beam waists. The researchers found that the surface plasmons provided strong overlap of the cavity mode with the gain from the conventional III–V material, compensating for the cavity losses and leading to lasing even at a material threshold gain of less than 700 cm^{-1}.

Compared with all-dielectric microcavity semiconductor lasers previously reported, the nanopatch lasers have much smaller cavity volumes and good output beam shapes. The researchers also point out that the devices may be suitable for integration into multifunctional microsystems and nanosystems.