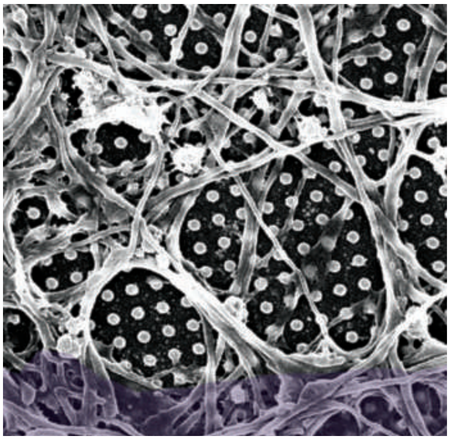
OPTICAL SENSING
Brain waves
Nano Lett. ASAP (2009) doi: 10.1021/nl801891q



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Researchers have successfully used plasmonic gold nanoparticles to detect brain cell activity. The work, performed by Jiayi Zhang, Tolga Atay and Arto Nurmikko of Brown University, could point the way towards reading local brain waves on a submicrometre scale.

Neuroscientists typically record brain activity using electrodes that are inserted into the cellular tissue, a method that is invasive and electronically noisy. Non-invasive approaches have been tried, but they usually involve dyes and staining techniques that are toxic or have other drawbacks. Localized surface plasmons (LSPs), which are confined to subwavelength-size metal nanoparticles, offer a potential way forward because they can perform non-invasive optical sensing on the micro- and nanoscale.

Zhang and colleagues started by growing mammalian hippocampal brain cells on a gold nanoparticle template. They then used the surface plasmon resonance of the nanoparticle array as a marker of brain activity: when a neuron fires and switches its potential, the resonance wavelength of the nanoparticle shifts, and neural activity can be mapped in real time.

Although previous research has used LSP resonances to detect nerve signals in rats, this is the first time that they have been used to detect the firing of a single brain cell. The question of how to deliver plasmonic nanoparticles into deep brain tissue remains unanswered, but could possibly involve colloidal nanoparticles or optical fibre implantation into the brain.

LASERS
High-performance QCLs
Appl. Phys. Lett. **94,** 011103 (2009)

Tremendous progress has been made in improving the performance of quantum cascade lasers (QCLs) in recent years. They now emit light in the entire mid-infrared range (3–25 μm), and are used in sensing, military applications and free-space communications. Qi Jie Wang and colleagues have unveiled a new high-performance QCL that is based on a three-phonon resonance design.

For optimal performance the QCL must maintain a large population inversion, which requires the efficient injection of electrons into the upper laser level and fast depletion of the lower level. Wang *et al.* focus on improving the depletion scheme using an effect known as longitudinal optical phonon scattering, which is the fastest intersubband relaxation process available. It ensures fast depletion and helps to maintain the required population inversion.

In their three-phonon scheme, four energy states in the laser's active region are separated from one another by the energy of an optical phonon. With so many energy levels, depletion is improved and thermal backfilling of the electrons from the active region ground state is greatly decreased. The resulting QCL emits light at 9 μm with a peak output power of 1.2 W. The authors also produce a smaller heterostructure device that offers continuous-wave power as high as 65 mW from a single facet at 300 K.

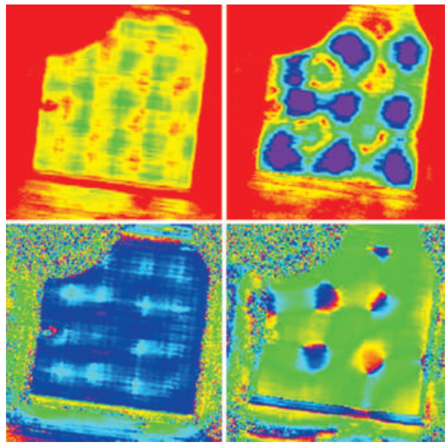
OPTICAL MICROSCOPY
To new depths
Proc. Natl Acad. Sci. **105,** 20221–20226 (2009)

Three-dimensional biological imaging is the focus of new research from Alipasha Vaziri and colleagues in the United States. They manage to image protein distributions in cells with a resolution better than 50 nm at multiple imaging planes up to 10 μm deep in a sample.

Most of the microscopy techniques currently available are limited to imaging depths that are a fraction of the optical wavelength. Biologists would like to study whole cells or organelles that typically appear up to 15 μm deep into the cell. Vaziri *et al.* combine a technique known as photoactivated localization microscopy (PALM) — whereby emissions from molecules are used to discriminate signal from background — with a method known as temporal focusing, which can be used to selectively excite a thin layer of molecules in a biological sample.

The combination of these two methods is used to excite and image a thin layer of fluorescent proteins several micrometres deep in a cell sample. The generated images, taken from mitochondrially labelled cells and the membranes of living *Drosophila* cells, show super-resolution over an axial range of about 10 μm, overcoming the depth limitation of more conventional techniques.

IMAGING
Acoustic world
Appl. Phys. Lett. **93,** 261101 (2008)



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Bulk acoustic wave (BAW) and surface acoustic wave (SAW) piezoelectric resonators are used in the communications industry to filter electromagnetic waves with frequencies ranging from 1 to 10 GHz. Thanks to their high *Q* factors (over 1,000), small volumes and relatively low price tags, they have the potential to be extremely useful in modern wireless communication systems. Compared with SAW resonators, BAW resonators are easier to couple to standard integrated circuit technology, handle power better and are generally more stable with temperature fluctuations.

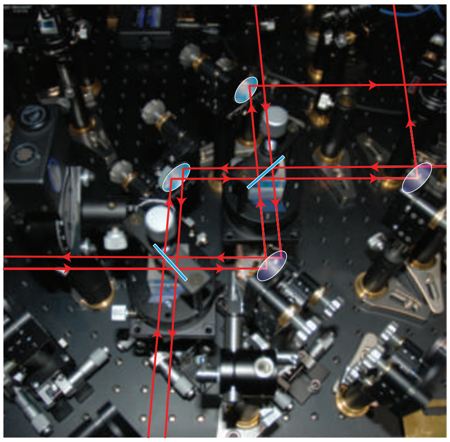
The bandwidth of these devices depends on the acoustic loss, and optical imaging has proved invaluable for monitoring resonator operation and acoustic wave leakage. Takashi Fujikura and colleagues have now used an ultrafast interferometric technique to image acoustic waves coming from a thin-film BAW resonator in real time.

They use ultrashort optical pulses (with a near-infrared wavelength of 830 nm) both to generate synchronized electrical pulses that excite the BAW resonator, and to detect the resulting surface vibrations. The technique can successfully image the amplitude and phase of waves with frequencies up to 2.2 GHz and measure both longitudinal and surface acoustic modes. By improving the response of the photodetector used, higher-frequency BAW devices could be probed, potentially up to >100 GHz.

QUANTUM OPTICS

Entanglement purification

Science **23,** 483 (2009)



HOKKAIDO UNIVERSITY

Distinguishing and sorting photons that possess desired features from those that do not is an important task in many optical applications. One example is the polarization filter that passes a photon only if it has a certain polarization.

For quantum information science, arguably the most important feature is the entanglement — a quantum mechanical coupling — of multiple photon states. If two states, such as the polarization of two photons, are entangled, it is not possible to describe one state without its counterpart. This feature is important for quantum information processing.

A Japanese–UK collaboration has now realized a non-destructive entanglement filter that transmits entangled photon pairs only if they share the same polarization. The two possible transmitted photon states are automatically sorted to separate output ports.

The entanglement filter is likely to be a key element for controlling multiphoton quantum states with a host of foreseeable applications in quantum communication and computing.

The team creates the photon pairs by passing pulses through a beta-barium borate crystal and filters them with an optical circuit made from an ultra-stable Sagnac interferometer featuring partially polarizing beam splitters. The sorting relies on the fact that photon pairs of different polarization combinations experience distinct path lengths. The measurement of an ancillary photon pair ensures that non-destructive successful filtering of a signal pair took place.

SOLAR TECHNOLOGY

Designer modules

Appl. Phys. Lett. **94,** 013305 (2009)

Scientists working for Sharp Corporation in Japan have produced a dye-sensitized solar cell (DSC) module with a record-breaking efficiency of 8.2%. Their work comes on the heels of other studies that have endeavoured to boost DSC sizes while maintaining reasonable efficiencies.

Liyuan Han and co-workers studied a DSC module made up of several rectangular cells connected in series. Because neighbouring cells are processed in reverse, the module is known as a W-contact module. By eliminating the amount of interconnection between neighbouring cells, the module can offer a larger active area — 25.5 cm^2 in this case. In an effort to increase the size of DSCs in recent years, researchers have tried connecting many single cells in series in various configurations.

The W-contact design increases the active area and produces neighbouring cells of alternate bias. However, the challenge is to maintain a uniform short-circuit current density across the entire module. Han *et al.* achieve this by optimizing the composition of the platinum counterelectrode, the electrolyte, the thickness of the titanium dioxide film used, and the uniformity of the unit cells. The result is the highest recorded module efficiency of 8.2%. With an active area of 85%, this equates to a 9.3% active area efficiency.

NONLINEAR OPTICS

Discrete phase jump

Phys. Rev. Lett. **102,** 013902 (2008)

The ability to change the phase of one light beam using another by means of a nonlinear interaction (cross-phase modulation) between the two has applications in fields such as quantum information, high-precision sensors and low-power optical switching. Schemes for cross-phase modulation, including electromagnetically induced transparency, typically allow the phase of the signal to be varied between 0 and 2π.

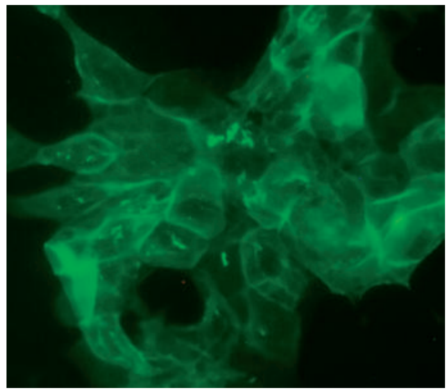
Ryan Camacho and US collaborators have now demonstrated all-optical modulation in which the phase change is either zero or π radians, with no possibility of the values in between. The discrete phase-jump scheme relies on an interferometer, in which a nonlinear interaction between control (852 nm wavelength) and signal (895 nm wavelength) fields is mediated by a 10-cm-long cell of warm (70 °C) caesium vapour. A solenoid in the gas chamber applies a magnetic field allowing magneto-optical Faraday rotation of the polarization.

The scheme works by flipping the phase to either 0 or π, depending on a threshold value for the phase of the signal that is significantly smaller than π. The discrete phase modulation may open new avenues for effective amplification and sensing of very weak interactions.

NANOPLASMONICS

Remote control genes

Nano Lett. ASAP (2009) doi: 10.1021/nl802689k



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Scientists based in the United States have come up with a new way of controlling gene interference in living cells: using light-absorbing nanoparticles and an optical remote control. Precise control of gene interference is important for studying cellular signalling pathways, quantitative cell biology and molecular biology.

The team's optical switches consist of double-stranded oligonucleotides attached to gold nanoparticles (GNPs), which are tuned to absorb in the near-infrared wavelength range, where cells are essentially transparent and undamaged by light. At specific times and cellular locations, a near-infrared laser is used to activate the GNP remotely (through a photothermal heating mechanism), which then releases about 250 molecules of oligonucleotides. These nucleotides bind to mRNA within the cell and silence the gene of interest at the translational step. This halts protein translation and expression in the cell.

Compared with conventional gene interference methods, the technique ushered in by Lee *et al.* has the advantage of offering both spatial and temporal control, minimal photodamage to cells, and the ability to couple the optical transmission frequency selectively to different nanoscale transmitters.