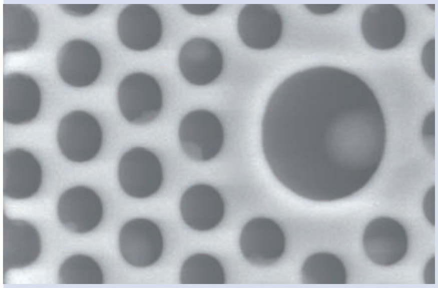
SENSING

Catching a cold



Opt. Lett. **32,** 3284–3286 (2007)

By concentrating an optical field, tiny optical microcavities can radically enhance the interaction between light and matter. Mindy Lee and Philippe Fauchet at the University of Rochester in the USA are taking advantage of this fact to create super-sensitive sensors.

Although the general concept is not new, the problem with many previous approaches has been that the tightly collimated beam required has necessitated the use of a large-area sensor. This in turn limits the minimum particle size that can be detected. The Rochester team uses silicon two-dimensional photonic-crystal cavities. Photonic crystals rely on the scattering from periodically arranged interfaces to confine light on the micrometre scale. The optical properties of cavities, created by intentionally introducing a defect into the otherwise perfect crystal, are very sensitive to any refractive-index changes in their environment, making them a promising solution.

The defect in the cavity used by Lee and Fauchet is a pore with a diameter of 685 nm, in which the target analyte becomes trapped. This corresponds to a sensing area of just 40 μm^2, smaller than any other design reported so far. To demonstrate this principle, they use 370-nm-diameter latex spheres. When the cavity catches a sphere, the resonance redshifts by approximately 4 nm, which is easy to detect. This size sensor is just right for the detection of a number of important viruses, including both influenza A and hepatitis.

SOLAR CELLS

Get in shape

Appl. Phys. Lett. **91,** 123514 (2007)

Conjugated polymers are rapidly gaining a reputation as serious competition for silicon when it comes to designing solar cells. They have the edge in terms of cost and they can also be used in flexible devices. Now, Kristofer Tvingstedt and colleagues at Linköping University in Sweden have demonstrated a very simple but effective way of increasing the efficiency of these structures.

Their idea is to change the geometry of the cell to ensure that as little light is wasted as possible. Starting with the conventional approach, the researchers spin a thin coat of polymer 50 nm to 60 nm thick and sandwich it between transparent electrodes. The exact composition of the polymer blend determines the wavelengths that are absorbed. Therefore, by using two cells with different active material in tandem it is possible to increase the range of wavelengths over which the device operates. Tvingstedt *et al.* arrange two such cells in a V-shape; any light reflected from one cell is directed onto the other. In fact, they show that this structure can almost completely absorb any light incident on it. Their approach avoids the problems that previous tandem cell designs encounter when trying to coat one layer onto another and the need for numerous electrical contacts. Despite the simplicity of the idea, the team were able to record an almost doubling of the power-conversion efficiency.

MID-INFRARED OPTICS

Tune in

Appl. Phys. Lett. **91,** 173113 (2007)

Apertureless near-field scanning optical microscopy enables imaging at a level below that imposed by diffraction. The two key elements are light and a nanoscale metal tip that is scanned across the surface of interest. Light scattered from the tip can be collected and holds enough information for high-resolution imaging. Nanfang Yu and co-workers from Harvard University and Agilent Laboratories in the USA, have combined the metallic tip and light source to create an integrated version of this concept, a so-called plasmonic laser antenna, which operates at mid-infrared wavelengths.

Nanfang *et al.* defined an optical antenna, made of two gold rods, on the face of a semiconductor laser. The rods were separated by 100 nm with the aim of magnifying the optical field in this space. The wavelength at which this is possible is controlled by varying the length of the rods. The team simulated structures with rods 70 nm thick and 125 nm wide and found that, for 7.0-μm-wavelength light, the rods must be 1.3 μm in length.

The researchers used an InGaAs/AlInAs quantum-cascade laser, and were able to observe light confinement on a scale one seventieth of the wavelength. The peak optical intensity between the two gold rods was estimated to be as high as 1 GW cm^{-2}. The team also showed that the same concept can be applied to a laser emitting at 5.3 μm, simply by scaling the antenna dimensions.

QUANTUM OPTICS

Single-photon maths

Science **317,** 1890–1893 (2007)

Quantum-mechanical quantities do not generally follow a commutation law — for instance, $m \times n$ doesn't give the same value as $n \times m$. Although this is well known, it is always fascinating to observe quantum-mechanical effects experimentally. Now, a group of researchers from Italy and the UK have performed an experiment that explicitly demonstrates that the two operations of photon creation and photon annihilation do not commute. For photon creation, Valentina Parigi and colleagues use optical parametric amplification to add a single photon to a light beam. The annihilation operation is performed by subtracting a single photon from the light beam using a beam splitter. They then measure the quantum-mechanical state of the resulting light field after each operation and after sequences of addition–subtraction and subtraction–addition. As expected, they saw a substantial difference when the order of the operations is reversed. However, the scientists were surprised to find that the subtraction of a photon, counterintuitively, leads to an increase in the mean number of photons in the light field, just as happens in the addition process. The scientists envisage that these exciting results will help engineer quantum light states, an ability crucial for the implementation of quantum information protocols.

PHOTOLUMINESCENCE

A long blink

Nano Lett. **7,** 3290–3295 (2007)

Richard Loomis and colleagues at Washington University, USA, have observed synchronous photoluminescence fluctuations, 'blinking', along whole quantum nanowires.

The researchers synthesized cadmium selenide nanowires with diameters of

3.5 nanometres, tens of micrometres long. They used commercial fluorescence microscopy apparatus, illuminating continuously at energies above the bandgap of the wires, to obtain photoluminescence images as a function of time. The images were mostly dim, with a photoluminescence yield of less than 1%, fluctuating by less than a factor of two. However the images also revealed jumps in the photoluminescence along the whole wire to yields of 20%.

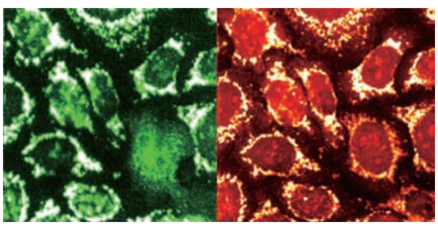
The probability distributions of bright and dark periods closely resembled that of the blinking in quantum dots and rods and the localized twinkling observed previously in quantum wires. However, there were some differences in the behaviour of the blinking along whole wires, such as the presence of a weak continuous photoluminescence signal during dark periods and a dependence on the illumination power.

The authors suggest that the absorption of a photon in the quantum wire can generate a one-dimensional exciton that is radially confined, but free along the length of the wire. Radiative recombination of these excitons would result in the synchronous whole-wire blinking. Simulations modelling the recombination of one-dimensional excitons matched the experimental data.

Nanowires are the smallest structures that can transport data along prescribed paths and have exceedingly high cross-sections per unit volume. Therefore these results could have potential applications in nanoelectronics and photovoltaics.

BIOPHOTONICS

Label free



Opt. Express **15,** 14184–14192 (2007)

Precise imaging of tissues and cells is essential for biology and medicine. Optical methods have the benefit of being non-invasive, but are hampered by the low optical contrast of most biological specimens, which means that cells usually need to be labelled with fluorescent molecules to be imaged. These fluorescent molecules can interfere with cell processes and can introduce misleading fluctuations into luminosity measurements due to variations in labelling specificity. Now Laurent Cognet and colleagues from the University of Bordeaux and the Institut Bergonié in France have demonstrated label-free imaging of mitochondria in cells.

Light-induced scattering around a nano-absorber has been used previously to detect gold nanoparticles. This method uses the influence on scattering of refractive-index changes caused by localized heating when a light absorber is illuminated. Cognet and co-workers combined this method with confocal fluorescence and white-light microscopy, and imaged live Cos-7 cells. Well-defined organelles with shapes and localizations similar to mitochondria were revealed.

Mitochondria are known to be good absorbers of light and the absorbing material was thought to be a protein called cytochrome c. However, by changing the morphological, structural and physiological states of the cells and analysing the imaging data, the authors ruled out the possibility of cytochrome c as the origin of the signals. The researchers suggest that the photothermal signals may come from an ensemble of proteins near the mitochondrial membrane, but further experiments are required to determine the origin conclusively.

The shape, spatial distribution and aggregation of mitochondria can be used to identify myopathies and cancer cells.

BIOMEDICAL IMAGING

A touch of CLASS

Proc. Natl Acad. Sci. **104,** 17255–17260 (2007)

Biomedical researchers working on the East Coast of the USA have developed an optical imaging technique that could open up new ways of studying living cells.

The approach developed by Irving Itzkan and colleagues — known as CLASS microscopy — combines the benefits of confocal light absorption with those of light-scattering spectroscopy. Confocal microscopy is a well-known high-resolution microscopic technique. Light-scattering spectroscopy relates the spectroscopic properties of light elastically scattered by small particles to parameters such as the particle size, refractive index and shape, and can probe structures much smaller than the diffraction limit.

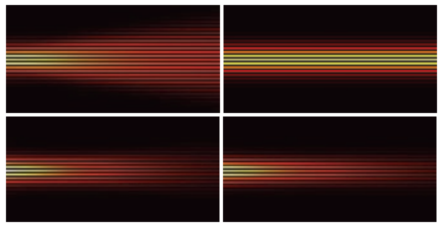
In contrast to other microscopy approaches, CLASS uses light-scattering spectra to provide very specific contrast between different cell structures. Itzkan and co-workers show that their approach can separate particles of varying sizes with an accuracy better than 10 nm, which is comparable to the resolution provided by transmission electron microscopes.

The crucial advantage, however, is that CLASS can map changes in living cells without destroying them. To demonstrate this, the team imaged living organelles in human bronchial epithelial cells that were undergoing induced cell death, and compared the shape changes to untouched living cells in real time.

This new method could prove useful to a number of fields: the study of cell death and cell ageing; drug discovery (for which drug-induced changes in cell shape are important); and perhaps even for monitoring the development of human embryos *in vitro* prior to implantation in the womb.

OPTICAL PHYSICS

Meta-magic



Phys. Rev. Lett. **99,** 153901 (2007)

Metamaterials with their unique optical, in particular nonlinear, properties based solely on their structure are driving a great number of investigations in labs around the world. Another exciting research area at the moment is enhanced light transmission through subwavelength structures owing to surface plasmon polaritons, which enables sub-diffraction-limited imaging. Now, what would be gained if these elements were to be amalgamated? Scientists from the University of California, Berkeley, in the USA, decided to find out.

Yongmin Liu and colleagues investigated theoretically so-called subwavelength metal–dielectric multilayers. These consist of alternating layers of metallic and nonlinear dielectric slabs. Their simulations show that these structures are able to self-focus light, creating solitons — discrete packets of light — at visible and near-infrared frequencies. The scientists attributed this effect to the threefold interplay between the periodicity and nonlinearity of the metamaterial and surface plasmon polaritons tunnelling through the structure; these three elements determine the size of the subwavelength soliton. These findings, say the researchers, will help future fundamental studies on nonlinear metamaterials as well as applications in subwavelength nonlinear optics.