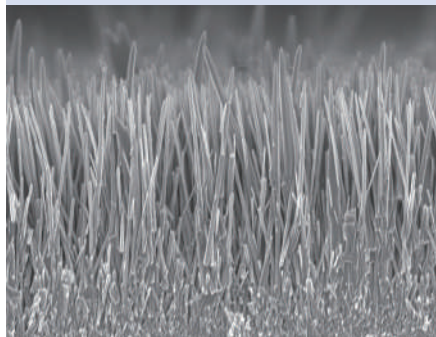


PHOTOVOLTAICS

Nano-improvement



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Nano Lett. **7**, 1793–1798 (2007)

A new nanotechnology-based approach to photovoltaic devices has been demonstrated by scientists at the University of Minnesota. The basic idea behind photovoltaics is fairly simple: light enters a semiconductor, is absorbed and creates two charge-carrying particles, an electron and a hole. The two particles are then quickly separated and carried to the device's electrodes.

Kurtis Leschkies and colleagues have now fabricated a photovoltaic cell that exploits the beneficial properties of quantum dots and nanowires to improve device performance. The key advantage of quantum dots is that their absorption wavelength can be easily controlled by varying their size. In addition, studies have indicated that more than one pair of charge carriers can be created per photon, making for a more efficient device. The nanowires provide a convenient direct electrical path from the quantum dot to the electrode.

In their device, Leschkies *et al.* used cadmium selenide quantum dots, 3–4 nm in diameter, attached to zinc oxide nanowires. These wires were 2–12 μm long and 75–125 nm across. The dots absorbed strongly at wavelengths between 500 nm and 600 nm and the cell had an internal efficiency of 50–60%. The team is not finished yet; they predict further advancements by improving the collection of the generated holes

wavelength tuning range of almost 45 nm is achievable for the fundamental mode. The researchers claim that this is the largest second-harmonic wavelength tuning range seen so far for single quasi-phase-matched period devices. Owing to the uniform strain applied along the entire periodic structure, the spectral profile and conversion efficiency are preserved.

This achievement makes PPSF attractive for use in tunable fibre laser sources and optical parametric oscillators. The team envisages that a broader tuning range can be reached by poling speciality fibres that have improved axial strength.

QUANTUM METROLOGY

Precision work

Science **316**, 726–729 (2007)

The idea behind quantum metrology is to use quantum mechanics to obtain highly precise measurements — better than classical physics can offer. Quantum entanglement of photons is a useful tool in this game and researchers in Japan and the UK are putting it to use. They have now shown that the so-called standard quantum limit can be broken using four-photon entanglement, with important implications for high-precision metrology.

The standard quantum limit represents the limit of how accurately a measurement can be made. It is not as stringent as the familiar Heisenberg uncertainty limit, and can in fact be overcome using quantum techniques, such as light squeezing or photon entanglement. So far, the standard quantum limit has only been beaten by using two entangled photons, but now Tomohisa Nagata and colleagues have exceeded it using four.

Nagata *et al.* used a specially designed, ultrastable interferometer to entangle four photons. First, a 780-nm femtosecond-pulsed laser is used to pump a nonlinear barium borate crystal, generating photon pairs. Two pairs of photons are then fed into different arms of the interferometer, passed through two sets of beam splitters, and the resulting interference fringes detected. According to quantum theory, for multiphoton interference, the visibility of the fringes needs to be high if the standard quantum limit is to be beaten — greater than 81% for four quantum-interfered photons. Nagata and co-workers measure a visibility of 91%, thanks to their very efficient interferometer. The result paves the way for ultrahigh-precision phase measurements, and biological sensing and quantum optical technology could benefit.

QUANTUM NETWORKS

Coherent state transfer

Phys. Rev. Lett. **98**, 193601 (2007)

The reversible coherent transfer of an atomic state between light and matter is a fundamental requirement for quantum networks, which have applications in quantum computation, communication and metrology. Allen Boozer and his colleagues have now demonstrated that a light state can be coherently stored in and retrieved from a caesium atom.

For some years now, the strong coupling between an atom and a cavity field has been recognized as a promising avenue towards achieving the reversible emission and absorption of a photon. However, although there has been much activity in the development of single-photon sources, so far no experiment has been able to verify the reversibility of the coherent emission or absorption processes.

Boozer and co-workers used a caesium atom coupled to a high-finesse Fabry–Pérot cavity. A complex system of laser pulses was used to pump the atom-cavity system and to probe its response. The timing between these various pulses was found to be crucial to optimizing the reversibility of the state transfer, and the

researchers were also able to determine the efficiency of the state transfer and confirm the coherence of the process.

The success of this procedure marks a significant advance on the road towards the realization of a quantum network protocol.

NONLINEAR OPTICS

At a stretch

Opt. Lett. Doc. ID: 81112 (2007)

A long interaction length and robustness against damage make periodically poled silica fibre (PPSF) an intriguing candidate for frequency conversion in fibre lasers. Now it comes with an even better feature — tunability.

Borrowing the tuning mechanism from fibre Bragg gratings technology, Albert Canagasabay and co-workers from the University of Southampton have demonstrated broad wavelength tuning of second-harmonic light generated from a quasi-phase-matched PPSF. Here, a silica fibre is specially designed by heating and cooling while an electric field is applied. A laser is then used to form a grating with a quasi-phase-matched period of 53.7 μm . The PPSF device is embedded in a steel and polymer beam, and when mechanically compressed a

INTEGRATED OPTICS

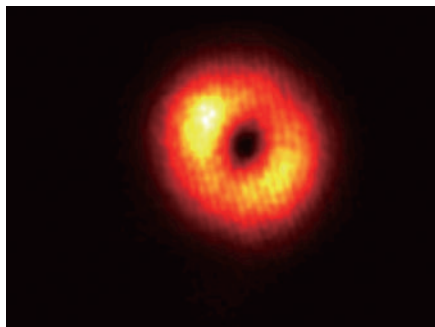
Light switch

Opt. Lett. Doc. ID: 81470 (2007)

Very small semiconductor optoelectronic switches with a low capacitance are now possible thanks to the efforts of researchers at Stanford University. Unfortunately, traditional silicon-based optical receivers are often limited by their large size and undesired power dissipation owing to a large photodiode capacitance. This stimulated Ali Okay and colleagues to come up with a nanoscale optoelectronic switch that operates in the telecommunication wavelength window (1.3–1.55 μm). Such a device could suit use as an optical latch for high-frequency optical clock distribution in future hybrid photonic–electronic chips. The switch combines a germanium optical detector with a silicon metal-oxide-semiconductor field-effect transistor (MOSFET) that provides the amplification mechanism. The team show that this device provides an amplified drain current up to three times higher than the germanium-gate current leading to high responsivity. The device also has a very low capacitance, which means that it has the potential to operate at very high frequencies, possibly at over 10 GHz. By using a graded SiGe gate region, the researchers expect to see further enhancement to the responsivity.

OPTICAL VORTICES

A lasting twist



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Phys. Rev. Lett. **98**, 203601 (2007)

A Laguerre–Gauss-mode light beam, also known as an optical-vortex beam, is ‘twisted’ so that any two diametrically opposed points at the centre of the beam have a π -phase shift, resulting in destructive interference and a dark centre. Now researchers in Israel have demonstrated that this optical vortex can be stored in a hot vapour of rubidium atoms for as long as 110 μs .

The team used a pump beam to populate the excited state of rubidium atoms at 65 °C, and on switching it off, sent a probe beam through that was stored in the atomic vapour. After a delay, the pump beam was switched back on, restoring the probe beam, which was imaged with a CCD camera. They compared the restored profiles for a Laguerre–Gauss beam, with a total waist of 670 μm , and a gaussian beam with an artificially darkened centre, 400 μm in diameter, provided by a beam stop. Whereas the dark centre of the Laguerre–Gauss beam was maintained, diffusion processes resulted in the centre of the gaussian beam being filled with light after only 30 μs . This result demonstrates the robustness of the number of twists, which characterizes a Laguerre–Gauss beam, against atomic-diffusion processes.

The authors suggest that the process could have possible applications in the storage of two-dimensional images.

PLASMONIC OPTICS

In focus

Opt. Express **15**, 6576–6582 (2007)

How can surface plasmon beams be focused? Scientists working in Denmark and Russia have shown that parabolic-shaped chains of nanoparticles could help to deliver intense plasmonic fields for use in biosensors, data-storage devices or integrated optical circuits.

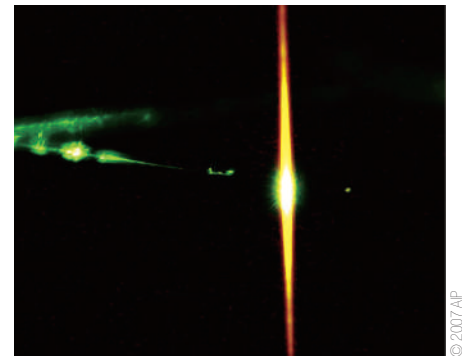
The potential of surface plasmon polaritons (SPPs) has been known for a long time, but only recently advances in nanofabrication techniques and near-field microscopy have taken us closer to building practical plasmon-based devices. For plasmonic technology to be successful, scientists must be able to do a number of things: launch SPPs and guide them; construct basic components such as interferometers, modulators and switches; and focus SPPs as and when desired.

It turns out to be more efficient to manipulate SPPs by treating their excitation and focusing as two separate stages. For this reason, Ilya Radko and colleagues excite SPPs by illuminating a straight gold metal ridge with a tunable laser (at normal incidence). As nanoparticle chains are very efficient SPP reflectors for oblique angles of incidence, Radko *et al.* used a parabola made from gold nanoparticles (about 250 nm wide and separated by 320 nm) to focus the SPPs travelling outwards from the ridge.

Using leakage radiation microscopy to track the SPPs’ field, the authors find that parabolas are efficient at focusing SPPs into submicrometre spots, with the curved shape minimizing the distance travelled by the plasmons (and therefore the propagation losses incurred). Parabolic ‘lenses’ could be another step along the path to plasmonic technology.

OPTOFLUIDICS

Capillary action



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Appl. Phys. Lett. **90**, 221101 (2007)

Dye lasers have been at the forefront of laser technology for many years, but they are limited by their large size and the inconvenience of handling toxic liquids. Now the advent of microfluidics — the control of the flow of fluids in very narrow channels — is making the fabrication of small and integratable dye lasers an exciting possibility. The question is how to best provide the optical feedback required for laser action. Now, Siyka Shopova and colleagues present a microfluidic laser that takes an intriguing route to creating this all-important feedback.

Optical ring resonators are a common feedback approach in small devices, using total internal reflection at a cylindrical interface to create so-called whispering-gallery modes. Shopova *et al.* use a capillary to accomplish this. They pass the dye rhodamine 6G through a silica capillary, the walls of which are thin enough (a few micrometres) for sufficient interaction between the mode on the edge of the capillary and the dye within it. When optically pumped, the 600-nm laser light can be easily collected by a fibre in contact with the capillary. The authors highlight that a number of lasers can share the same capillary, and the operation wavelength can be tuned easily by using a different dye. The result is a versatile, small-scale device that will probably be useful for lab-on-a-chip experiments.