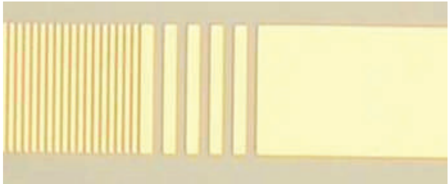
PLASMONICS

Electrically driven plasmons

Phys. Rev. Lett. **104,** 226806 (2010)



Surface plasmons — electromagnetic modes bound to a metal–dielectric surface — are typically generated using bulky optical set-ups that rely on carefully optimized coupling of the plasmons to free-space or guided light beams. Arthur Babuty and colleagues in France have now demonstrated an integrated scheme for electrically generating surface plasmons in a semiconductor. Light from an integrated quantum cascade laser operating at 7.5 μm was efficiently routed into a metallic strip plasmonic waveguide via a grating. The InP-based quantum cascade lasers were fabricated in ridges 22 μm wide and 4 μm deep. Distributed feedback for the laser was provided by a metallic–dielectric surface relief grating patterned using electron-beam lithography and a lift-off technique, and successful waveguiding was confirmed by scanning near-field microscopy. This result provides further hope for building practical integrated plasmonic circuitry.

QUANTUM ENTANGLEMENT

High-NOON states

Science **328,** 879–881 (2010)

In optics, the generation of multiphoton entangled states (known as 'NOON' states) with a large number of photons is appealing because it potentially allows highly precise phase measurements, yielding the prospect of 'phase super-resolution' and sub-Rayleigh resolution in quantum lithography. Until now, the generation of optical NOON-like states with more than three photons has only been possible using state projection or post-selection schemes. Now, Itai Afek and co-workers at the Weizmann Institute of Science in Israel propose an alternative generation method that involves the multiphoton interference of quantum light with classical light. Classical light (120-fs pulses at 808 nm from a Ti:Sapphire laser) was mixed in a beamsplitter with quantum light (entangled photon pairs generated by spontaneous parametric down-conversion). N-photon coherence of the generated states was verified by a Mach–Zehnder interferometer. A NOON state with $N = 5$ was obtained using 215 mW of ultraviolet pump power and with the amplitude ratio (classical light to quantum light) set to 2.16. The visibility of the NOON states for a five-photon coincidence was (42 ± 2)%, which significantly exceeds the super-resolution limit for classical states. Although the experimental implementation has so far only been demonstrated for $N = 5$, it should in principle be possible to extend it to larger photon numbers.

QUANTUM COMMUNICATIONS

Channel multiplexing

Phys. Rev. A **81,** 062301 (2010)

Entangled photon states have attracted much attention in recent years for their application in quantum teleportation and quantum key distribution, with Einstein–Podolsky–Rosen (EPR) entangled optical states in particular having the potential to enable quantum communication channels between two distant parties. Now, Boris Hage and co-workers at Hannover University in Germany have shown that a broadband squeezed light field can support frequency channel multiplexing for such EPR states, opening the door to more efficient quantum information processing at much higher transmission rates than are currently available. For example, each channel could serve as a resource for independent quantum key distribution or teleportation protocols. Hage and his colleagues generated a single broadband squeezed field at a wavelength of 1,064 nm using a half-monolithic single-ended standing-wave nonlinear cavity and optical parametric amplification. To implement the interference of two squeezed states defined at different Fourier frequencies, three triangular travelling-wave filter cavities were used. One of the filter cavities was used as a frequency beamsplitter that spatially separated the upper and lower sideband components of the broadband squeezed field. The filter cavity was detuned by −7 MHz with respect to the carrier field at 1,064 nm, allowing it to transmit the field of lower sidebands while reflecting the upper sidebands. The inseparability criterion for the presence of entanglement in the quadratures of the two fields was obtained as 0.41 ± 0.02, and the value of EPR paradox was 0.64 ± 0.02.

MAGENTO-OPTICS

Ultrafast magnetic switching

Appl. Phys. Lett. **96,** 201108 (2010)

The development of ultrafast magnetic switching technology is desirable for use in future ultrahigh-speed data storage and information processing systems. The recent news that Zuanming Jin and colleagues from Shanghai University and Fuzhou University in China have demonstrated all-optical magnetic switching on a timescale of ~500 fs suggests that photonics may have an important role in this development. The approach relies on a $NaTb(WO_4)_2$ crystal, the inverse Faraday effect (using light to manipulate a magnetic state) and ultrashort laser pulses. The team chose $NaTb(WO_4)_2$ for its low absorption in the visible and infrared regions, and for its customizable magneto-optical effects. The researchers used a pump–probe technique to measure the all-optical magnetic switching behaviour of the crystal. Light pulses of width 120 fs, photon energy 1.55 eV and repetition rate 1 kHz were used for both the control and signal beams. A broadband half-wave plate was used to rotate the polarization of the signal beam to 45° while both the linearly

QUANTUM OPTICS

Single-atom EIT

Nature **465,** 755–758 (2010)

Electromagnetically induced transparency (EIT) is a well-known nonlinear effect that allows the transmission of a probe beam through an optically dense medium to be manipulated by a control beam. A team of researchers from the Max Planck Institute for Quantum Optics in Germany and the Federal University of São Carlos in Brazil have now demonstrated EIT at the single-atom level — a scale many orders of magnitude smaller than in previous atomic ensembles. Single-atom EIT was confirmed by two observations: a frequency shift of the vacuum-Rabi resonances in the atomic transmission spectra, and the narrowing of the transmission window, which testifies to the existence of a coherent dark state. The researchers also demonstrated that the number of atoms in the system can be scaled up one-by-one. Because the number of photons that can be stored in a medium cannot exceed the number of atoms, this allows such an atom-number-tailored system to function as a highly nonlinear beamsplitter that subtracts a well-defined number of photons from a coherent input field. This study shows that individual atoms can act as quantum-optical transistors, with the ability to coherently control the transmission of light through a cavity. Such systems therefore have potential applications in the implementation of quantum computing protocols.

polarized signal beam and the circularly polarized control beam were focused onto the crystal. The researchers observed switching (spin-flips) on a timescale as short as 500 fs at room temperature, with a peak contrast ratio as high as 17 dB for a control beam fluence of 60 mJ cm^{-2}. Although the control beam currently requires high optical intensities to achieve switching, the researchers say that performance could be improved by implementing the crystal in a waveguide structure with higher confinement.

DRUG DELIVERY

Biological ballistics

Appl. Opt. **49,** 3035–3041 (2010)

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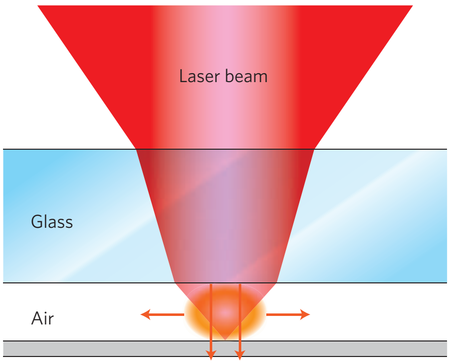


Those that hate the sight of needles and syringes at the doctor's clinic will be pleased to hear that a painless alternative may now be in sight. Tae-hee Han and colleagues from Seoul National University in Korea have demonstrated an optically driven microparticle delivery scheme that could become a means of administering precisely controlled drug doses through the skin. The researchers covered a metal foil in 5 μm cobalt microparticles and then ablated it using 10-Hz pulses of wavelength 532 nm and duration 5–9 ns from a *Q*-switched Nd:YAG laser. The resulting laser-induced plasma caused the foil to recoil and thus eject the microparticles outwards towards a layer of gelatine water used to mimic biological tissue. The microparticle penetration depth, which was a few millimetres in the work of Han and co-workers, can be controlled by adjusting the focal area on the film, either by varying the index of refraction of the confining material, the focal length of the lens or the distance between the lens and the surface.

GREEN LASERS

InGaN diodes show promise

Appl. Phys. Express **3,** 061003 (2010)

Adrian Avramescu and co-workers from Osram Opto-Semiconductors in Germany have reported an InGaN laser diode grown on c-plane GaN that operates in the wavelength range of 524–532 nm, representing a positive step forward for the realization of practical green semiconductor laser diodes for use in mobile full-colour projectors and other display applications. At 524 nm, the researchers achieved continuous-wave output powers of up to 50 mW at a temperature of 25 °C for a current of around 300 mA. The wall-plug efficiencies of their devices reached as high as 2.3%. This news is the latest in a string of promising reports over the past 18 months that have seen green InGaN lasers reach higher output powers and longer wavelengths approaching the ideal green window of 530–535 nm. The researchers say that their latest results suggest that the main limiting factor for achieving high-performance green lasers is related to the crystal quality of the In-rich InGaN quantum wells, rather than to piezoelectric-based red-shift resulting from the high In-content required, as was previously thought.

HIGH-FIELD OPTICS

Fibre-optic amplification

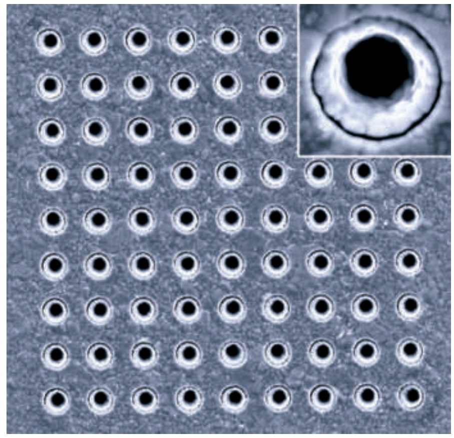
Opt. Lett. **35,** 1786–1788 (2010)

Optical parametric chirped pulse amplification (OPCPA) — a scheme that combines optical parametric amplification (OPA) with chirped pulse amplification (CPA) — is a highly efficient way of generating high-energy ultrashort pulses. However, OPCPA schemes traditionally use nonlinear crystals, which are bulky and require careful alignment. Now, Christophe Caucheteur and colleagues from France, Belgium and Spain have experimentally demonstrated OPCPA in an all-fibre configuration. The researchers used a fibre-based OPA scheme and combined it with a 15-cm-long linearly chirped fibre Bragg grating to perform pulse stretching and compression. Unlike in conventional OPCPA, the parametric amplification process was realized through the third-order nonlinearity of a 500-m-long highly nonlinear fibre. The team successfully amplified picosecond Fourier-transformed 1,550-nm pulses by 24.6 dB, following which the pulses were recompressed to their initial durations without any significant spectral or temporal distortions. The researchers say that it should also be possible for a fibre-based scheme to achieve amplification at wavelengths of ~1 μm — a spectral region important to most laser–matter interaction experiments.

NANOPHOTONICS

Reliable SERS

Nano Lett. **10,** 2231–2236 (2010)



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Surface-enhanced Raman scattering (SERS) usually relies on exploiting the large electromagnetic fields generated in a dielectric gap between two metallic structures. Unfortunately, the hotspots provided by nanoparticles in solution are random, and consequently reproducible fabrication of sub-10-nm gaps of well-controlled shape and orientation in a solid-state architecture is challenging. Hyungsoon Im and colleagues at the University of Minnesota in the USA may now have found a simple way around this problem, demonstrating the consistent fabrication of sub-10-nm nanogap arrays with various shapes and orientations through lithography and etching. In their experiments, more than 90% of the total area of the nanogap array substrates exhibited Raman enhancement factors of $>10^5$. In comparison, reference silver particle substrates achieved enhancement factors of $>10^5$ over less than 1% of their total surface. The researchers used optical lithography to fabricate an initial metal (silver) pattern, after which a sacrificial alumina layer whose thickness defined the nanogap was then deposited using atomic layer deposition. The second layer of metal was deposited and the structure was then anisotropically etched to expose the thin alumina sandwiched in between the metal layers. Alumina etching was then used to evacuate the gap. The substrate was incubated in 1 mM of benzenethiol, a well-characterized and efficient Raman scatterer, which was excited in the vicinity of the silver–air–silver nanogaps by a 514.5 nm laser spot that was scanned over the structures for the spatial analysis of the Raman spectra and enhancement factors.