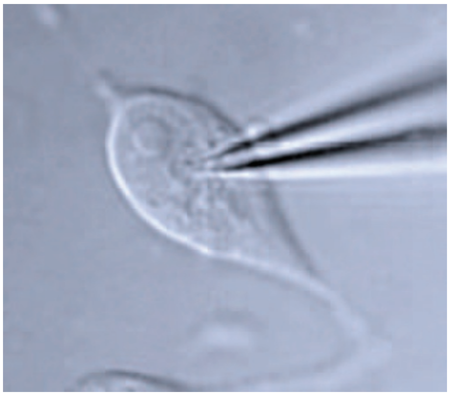
NEUROPHOTONICS

Quantum-dot control

Biomed. Opt. Express **3,** 447–454 (2012)



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The ability to switch and control electrical signals in the brain would help researchers tackle many of the outstanding questions in neuroscience. Katherine Lugo and co-workers from the University of Washington in the USA have now demonstrated an optical control scheme that uses quantum dots to control cellular activity and signalling. Optically exciting a quantum dot creates an electric dipole moment that can perturb the ion channel signalling capability of any cells nearby. The advantage of this approach is its flexibility: quantum dots can be activated and deactivated simply by turning on and off the excitation light, and can also be selectively bound to specific biological targets by modifying their surface chemistry. The researchers demonstrated the remote switching of cellular activity in cultured prostate cancer cells on CdTe quantum dot films, as well as cultured neurons on CdSe quantum-dot films and CdSe quantum-dot probes under excitation at wavelengths of 430 nm and 550 nm, respectively. They observed that these effects began to appear at an intensity rate of 10^{7} photons per square micrometre per second. *RW*

SEMICONDUCTOR LASERS

Pushing the mid-infrared

Appl. Phys. Lett. **100,** 041109 (2012)

The only semiconductor lasers currently capable of accessing mid-infrared wavelengths above 2.3 μm — a range that is particularly important for trace-gas optical detection — are those based on GaSb. Alternative InP-based devices, which offer the benefits of being cheaper, exhibiting lower thermal conductivity and relying on more established technology, are limited to an upper wavelength of around 1.75 μm. Stephan Sprengel and co-workers have now demonstrated room-temperature lasing at 2.55 μm in an InP-based GaInAs/GaAsSb type-II quantum-well laser operating in pulsed mode. The device employs compressive strain in both the GaInAs and GaAsSb regions, together with carrier confinement provided by electron- and hole-blocking layers made from AlAsSb and AlGaInAs, respectively. Whereas previous attempts exploited superlattice active regions, the device demonstrated by Sprengel and co-workers employs W-shaped active regions to benefit fully from the reduced density of states of the quantum confinement. The researchers also demonstrated continuous-wave lasing at 2.31 μm for temperatures of up to 0 °C. Although the device is still in the early stages of development, the researchers say that growth optimization and additional advances in design are expected to improve laser performance and extend operation further into the mid-infrared. *JB*

X-RAYS

Inner-shell atom laser

Nature **481,** 488–491 (2012)

X-ray free-electron laser (FEL) facilities provide pulses of soft and hard X-rays that are bright and short but suffer from unstable emission spectra. Nina Rohringer and colleagues from the USA and Germany have now found a way to improve the fluctuating spectrum, noise and limited coherence of an FEL. The team used the FEL at the Linac Coherent Light Source in the USA to pump a hard-X-ray atom laser and obtain narrowband and coherent output. The team used 40–80 fs pulses with photon energies of around 960 eV (wavelength of 1.28 nm) to illuminate a neon gas with a 1–2 μm spot size and thus produce a plasma column of core-excited ions. Amplified stimulated emission occurred at the front of the plasma column when photons emitted from previously excited atoms encountered atoms prepared in an excited state due to the FEL pulse. The researchers detected atomic radiation at 849 eV (wavelength of 1.45 nm) using a grating spectrometer and a CCD. To confirm exponential amplification of the X-rays along the gain medium, the researchers doubled the FEL energy from 0.12 mJ to 0.24 mJ, which increased the output by four orders of magnitude. Single-shot experiments provided a peak output of around 1.1 μJ and an effective gain coefficient of approximately 70 cm^{-1}. *DP*

OPTICAL CLOCKS

Stable transfer

Appl. Phys. Express **5,** 022701 (2012)

By phase-locking two independent clock lasers to a common optical frequency comb, scientists in Japan have successfully transferred the high stability of a master clock laser to a slave clock laser, which usually exhibits inferior performance. The team, from the National Institute of Information and Communications Technology (NICT) and the Japan Science and Technology Agency, say that the technique will prove useful for applications related to optical frequency standards and ultraprecise spectroscopy. The 729 nm

EXCITONS

Nanotube answer

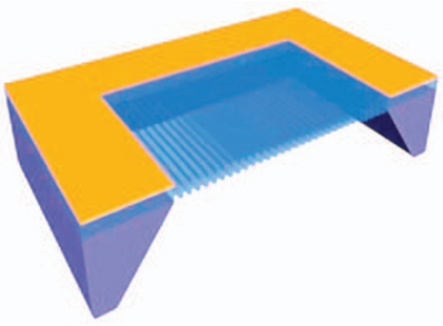
Phys. Rev. B **85,** 045428 (2012)

In metallic materials, free electrons can screen the Coulomb interaction between an electron and a hole, thereby preventing the formation of an exciton. Furthermore, the observation of photoluminescence in metallic materials is difficult because of the ultrafast non-radiative decay of photoexcited electrons and holes due to electron–electron scattering and photon-mediated relaxation processes. Takeshi Koyama and co-workers from Nagoya University and the National Institute of Advanced Industrial Science and Technology in Japan believe they have now found evidence of exciton formation in metallic single-walled carbon nanotubes (SWNTs). The researchers used femtosecond time-resolved luminescence spectroscopy to measure the photoluminescence. The device provided a central excitation photon energy of around 1.55 eV and a time resolution of 10 fs. The researchers prepared samples enriched with both metallic and semiconducting SWNTs by using the density gradient ultracentrifugation procedure. They attributed the peak in photoluminescence — around 1.4 eV — to the metallic-SWNT-enriched samples. They also implemented transient photoabsorption measurements to record the time evolution of band bleaching around 1.4 eV. The difference in temporal behaviour between the photoluminescence and absorption signals strongly suggests that the photoluminescence peak was excitonic in nature. The exciton lifetime of 40 fs indicates that a large exciton binding energy leads to a relatively stable exciton state in the presence of metallic electrons. *NH* master clock laser used in the experiment is reportedly the most stable clock laser at NICT, whereas the 698 nm slave clock laser, being based on a ^{87}Sr transition, is inherently less stable. The researchers used an optical frequency comb generated by a Ti:sapphire laser to bridge the frequency gap between the two lasers and applied a feedback-signal driven acoustic optical modulator to correct for fluctuations in the frequency of the slave laser. They measured a factor of two improvement in stability (from 4.4×10^{-15} to 1.9×10^{-15}) for the phase-locked slave laser. The researchers are now attempting to reduce thermal noise and improve the inherent stability of the slave laser by cooling pure-silicon optical cavities to temperatures of around 120 K. *OG*

NANOPHOTONICS

Circuit design

Nature Mater. **11,** 208–212 (2012)



Electronic elements such as resistors, inductors and capacitors are commonly used as building blocks to control and manipulate radiofrequency signals in electronic circuits. Nader Engheta and co-workers previously proposed that optical nanostructures, if properly designed and judiciously arranged, could behave as analogous nanoscale circuit elements for use at optical frequencies. The researchers have now experimentally verified their predictions by using arrays of nanorods to build a two-dimensional optical nanocircuit that operates at mid-infrared wavelengths. The researchers designed and fabricated arrays of Si_3N_4 nanorods and then quantitatively evaluated the equivalent impedance of these nanostructures in the mid-infrared regime. Using Fourier transform infrared spectroscopy, they showed that the nanostructures can indeed function as two-dimensional optical circuit elements. In addition, the connections between the nanocircuit elements, in particular whether they function in a series or parallel arrangement, can be controlled through the polarization of the optical control signals. The researchers say that introducing optical nonlinearity into such optical circuits could provide a platform for mixing multiplexing optical signals with different incidence angles and polarizations. *JB*

QUANTUM CASCADE LASERS

Chasing room temperature

Opt. Express **20,** 3866–3876 (2012)

Research is continuing in the quest to demonstrate room-temperature terahertz quantum cascade lasers (THz QCL). The main problem is that the gain of a THz QCL depends on the product between population inversion and oscillator strength, which are difficult to optimize simultaneously. Saeed Fathololoumi and co-workers from the National Research Council of Canada, the University of Waterloo, the Massachusetts Institute of Technology, Technische Universität München and Shanghai Jiao Tong University have now used a density matrix approach to maximize the gain of a THz QCL and achieve lasing at a temperature of 199.5 K. The THz QCL was based on GaAs/$Al_{0.15}Ga_{0.85}As$ and had a three-well structure. The active region thickness, ridge width and length of the device were 10 µm, 144 µm and 1 mm, respectively. The researchers reduced the waveguide loss within the QCL by fabricating a Cu–Cu double-metal waveguide without a top n^+ contact layer. The device produced single-mode emission at a wavelength of 3.22 THz when electrically driven with a pulse duration of 300 ns at a repetition rate of 300 Hz. The researchers measured a threshold current of around 1.92 kA cm^{-2}. *NH*

QUANTUM COMMUNICATION

Frequency conversion

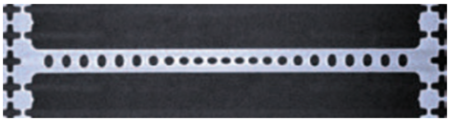
Phys. Rev. A **85,** 013845 (2012)

Quantum communication networks rely on optical devices such as quantum light sources, optical fibres, quantum memories and photodetectors. Unfortunately, each type of device has its own optimal wavelength of operation; 1,550 nm for optical fibre, 800 nm for quantum memories using rubidium vapour, and visible light for a silicon-based photodetector. Quantum frequency converters, which can change the wavelength of a photon while preserving its indistinguishability, single-photon character and entangled state, are therefore extremely important tools. Sven Ramelow and co-workers from the University of Vienna, the Austrian Academy of Sciences and the Austrian Institute of Technology have now demonstrated a quantum frequency-conversion scheme based on sum-frequency generation. First, the researchers generated polarization-entangled photon pairs at a wavelength of 810 nm by spontaneous parametric downconversion in a periodically poled $KTiOPO_4$ crystal. They were then combined this signal beam with 1,550 nm pump beams in two orthogonally oriented $KTiOPO_4$ crystals. The horizontally and vertically polarized components of the signal beam were converted to 532 nm beams in the first and second crystals, respectively. To render the output photons indistinguishable, the researchers used a pair of birefringent calcite wedges to compensate for the temporal walk-off of 1.8 ps between the orthogonal polarization components. This resulted in the successful transfer of entanglement between the 810 nm and 532 nm photons. *NH*

OPTOMECHANICS

Quantum motion

Phys. Rev. Lett. **108,** 033602 (2012)



Amir Safavi-Naeini and colleagues at the California Institute of Technology in the USA have used lasers to cool a mesoscopic optomechanical resonator down to a phonon occupancy of just 2.6 ± 0.2 — a level that allows characteristics associated with quantum zero-point fluctuations to be observed. The team used a silicon microbeam patterned with air voids that forms a Bragg cavity at the centre of the beam for both the photonic modes and the acoustic mode. The photonic modes at 1,545 nm and 1,460 nm were used for readout and optical cooling, respectively. The in-plane breathing mechanical mode, which had a frequency of around 4 GHz, was coupled to the optical modes by radiation pressure. Although photon cooling to the single-phonon level has already been achieved in related systems, the researchers say the performance of their set-up (with a minimum observed phonon number of 2–3) is currently limited by the power of the cooling laser and is therefore open to improvement. They also noted that the results deviate from ideal predictions due to optical absorption, which causes power-dependent variations in the parameters. *DP*

Written by James Baxter, Oliver Graydon, Noriaki Horiuchi, David Pile and Rachel Won.