

demonstrated a micropillar-array terahertz laser with a pillar size that is much smaller than the emission wavelength. A bulk heterostructure with a 10- μm -thick GaAs/ $\text{Al}_{0.15}\text{Ga}_{0.85}\text{As}$ quantum cascade structure designed for an optical gain of around 4 THz is etched to become a pillar array by reactive ion etching. The 5- μm -diameter micropillars have a filling factor of 0.75 and are arranged in a hexagonal lattice with array sizes up to $1,000 \times 120 \mu\text{m}$. Lasing emission is observed up to a maximum temperature of 55 K. Because the lattice periodicity is significantly smaller than the emission wavelength, the micropillar array can be considered a homogeneous effective medium rather than a photonic crystal. Consequently, the array resonator is not defined by the distributed feedback of a photonic crystal; instead it operates as a Fabry–Pérot resonator defined by the boundaries of the array. The observed threshold current density of the laser is approximately 0.65 kA cm^{-2} . As each pillar can be pumped individually, the researchers claim that the pumping geometry can be changed dynamically. *NH*

MOLECULAR LASERS

Methanol spans far infrared

IEEE J. Quantum Electron. **50**, 23–24 (2014)

Sumaya Ifland from Edmonds Community College and co-workers from Central Washington University in the USA have successfully generated 43 new emission lines in the far-infrared range (106.4 μm to 700.3 μm) by optically pumping an isotopic form of methanol, $^{13}\text{CHD}_2\text{OH}$. This is the first time that laser radiation above 100 μm has been generated from this particular substance. The researchers found these emissions by varying the length of the cavity of the molecular laser system and pumping the cavity using a carbon dioxide laser. The far-infrared laser emissions were detected using a liquid-helium-cooled silicon bolometer operating at a temperature of 4 K. Previously, eight laser lines of $^{13}\text{CHD}_2\text{OH}$ had been identified at wavelengths below 100 μm . The newly discovered emissions above 100 μm suggest that $^{13}\text{CHD}_2\text{OH}$ is promising as an optically pumped laser medium, especially for generating terahertz radiation for spectroscopic applications. *SP*

PHOTOACTUATORS

Nanotube motors

Nature Commun. **5**, 2983 (2014)

Light-driven mechanical motors, deformable disks and actuators have been fabricated by coating 10- μm -thick disks

of polycarbonate with a layer of single-walled carbon nanotubes. On exposure to light, these bilayer disks deform and curl up as a result of photothermal effects. The deformation is fast and reversible, and can produce large deflection angles. In particular, when placed directly under a solar simulator with a 1-sun intensity, the structures bent $\sim 90^\circ$ within 0.7 s and then relaxed back to their original flat state within 0.9 s when the light is turned off. Furthermore, centimetre-scale cylindrical structures made from the bilayer can act as a motor, generating a torque that allows them to roll at a speed of 6 cm s^{-1} when illuminated with light from a halogen lamp. Tests indicate that such structures can survive 60,000 actuation cycles. By using carbon nanotubes with a different chirality, it is possible to tune the response wavelength of the structures. The developers from the University of California at Berkeley, Lawrence Berkeley National Laboratory and Northwestern University in the USA suggest that their structures could find applications as sun-driven motors, light-activated smart curtains and sensors. *OG*

NONLINEAR OPTICS

Phase match freedom

Science **342**, 1223–1226 (2013)

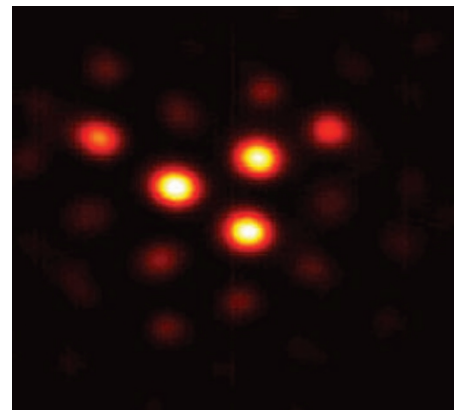
To maximize nonlinear effects, it is vital to match the phases of light beams that are involved in the interaction; this requirement is a consequence of the need to conserve the momentum of photons. Usually, this limits the wavelengths and beam directions that can be used in nonlinear processes, and necessitates the use of birefringent, periodic or carefully orientated materials to minimize any phase mismatch. The advent of artificially engineered metamaterials, however, has now provided researchers with a new opportunity to overcome these restrictions. Haim Suchowski and co-workers from the University of California at Berkeley and Lawrence Berkeley National Laboratory have now realized a metamaterial with a zero refractive index in which photons carry zero momentum. The result is momentum conservation is possible for photons travelling in both the backward and forward directions. The team has demonstrated equally efficient bidirectional four-wave mixing in a ‘fishnet’ zero-index metamaterial. The structure is composed of a stack of alternating thin metal (30-nm-thick gold) and dielectric (50-nm-thick magnesium fluoride) layers and features an array of cross-shaped holes.

Such zero-index materials may prove useful for applications involving other nonlinear processes, such as sensing based on Raman spectroscopy and the generation of entangled photons by spontaneous parametric downconversion for quantum optics applications. *OG*

NONLINEAR OPTICS

A twister of light bullets

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Vortex solitons are of interest because they possess orbital angular momentum fields that are capable of carrying data and energy and, being solitary waves, are robust against diffraction and crosstalk. Now, Falk Eilenberger and co-workers from Friedrich-Schiller-Universität Jena and the Institute of Photonic Technology in Germany report what they claim is the first observation of vortex light bullets — discrete, spatiotemporal, solitary waves with orbital angular momentum. The vortex light bullets are excited in photonic-crystal fibre arrays (with a solid core of increased refractive index instead of air holes, a core radius of 10.3 μm and a centre-to-centre distance of 34.7 μm) by femtosecond pulses, and analysed with a spatiotemporal cross correlator. By performing experiments and rigorous simulations, the team found that, unlike ordinary light bullets, vortex light bullets decay into a set of desynchronized light bullets after a considerable propagation length. Furthermore, they are robust against higher-order effects and asymmetric excitation, occur in a limited energy window, and are characterized by temporal and energetic synchronization up to a certain sample length. These findings provide valuable insights into the complex behaviour and internal dynamics of vortex light bullets. *RW*

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