NONLINEAR OPTICS

3D light bullets

Phys. Rev. Lett. **105,** 263901 (2010)

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A clearer understanding of the formation of light bullets — intense, stable spherical pulses of light — would represent a significant advancement in the field of nonlinear dynamics. Stefano Minardi and colleagues from Germany, Spain and Israel have recently investigated and observed such 3D stable localization of light pulses using a 2D hexagonal array of single-mode fibre waveguides. The 40-mm-long device is formed by 91 silica cores, each with lattice periods of 33.2 ± 0.4 μm and core radii of 9.8 ± 0.2 μm, embedded in fluoride-doped silica glass with an index contrast of 1.2×10^{-3}. The waveguides together represent a system with quasi-instantaneous cubic nonlinearity and a periodic, transversally modulated refractive index that confines high-intensity light to travel just as it would in a simple single-mode fibre. A 170 fs infrared laser pulse centred at 1,550 nm was used to excite the central waveguide of the array. The team obtained good agreement between the measured and computed spatiotemporal profiles in different operating regimes. Time-gated images and spectra revealed the evolution of the light bullets, which may aid the design of systems aimed at realizing long-lived light bullets.

ORGANIC LASERS

Stretchable and tunable

Adv. Mater. doi:10.1002/adma.201003108 (2011)

Organic lasers are attractive for their broad tuning range and wide spectral coverage. Their ability to be optically tuned simply by mechanical stretching may provide a range of new applications in biology, chemistry and structural monitoring. Patrick Görrn and co-workers from the USA and Germany now present an approach for the self-organized fabrication of tunable organic lasers based on stretchable distributed feedback gratings. The gratings were fabricated on the surface of elastomeric poly(dimethysiloxate) (PDMS) through a prestretching and post-relaxing processes. The PDMS sample was first treated with oxygen plasma to harden its surface, after which the relaxation process caused the surface to buckle into highly ordered gratings. An organic gain medium was then spin-coated on top of the gratings. The team observed lasing at a low threshold of 28 μJ cm^{-2} when the gratings were excited with 355 nm light from a *Q*-switched solid-state laser. They also demonstrated that stretching the gratings by up to 2.2% allowed continuous tuning from 633.6 nm to 638.3 nm, and said that 10% stretching (corresponding to a tunability of 20 nm) is theoretically possible, making this device potentially useful as a large-area elastic laser.

CONDENSED MATTER

Ultrafast manipulation

Opt. Express **19,** 1260–1270 (2011)

The ability to change the material phase of a chalcogenide alloy is essential for enabling optical data storage. Unfortunately, however, the kinetics of rapid phase change are still being actively debated, the speed limitations of switches and memories based on such materials are relatively unknown, and the direct optical manipulation of atomic structures has yet to be reported. Now, Kotaro Makino and colleagues from Japan have used a pair of femtosecond light pulses to demonstrate optical non-thermal manipulation of atomic arrangements in $Ge_2Sb_2Te_5$. The researchers demonstrated an amorphous to crystalline phase change in $Ge_2Sb_2Te_5$ by selectively exciting a vibrational mode of $GeTe_4$ in its amorphous phase. 20 fs near-infrared pulses were used to excite the vibrations and a pump-pulse pair was generated using an interferometer. The phase change only occurred when the time separation between the two pulses was resonant with the local vibration. The researchers believe that the crystallization process took around 1 ps. These results may help the push towards terahertz switching and terabit-per-second data transfer rates.

QUANTUM ENTANGLEMENT

Optically controlled spins

Nature Phys. doi:10.1038/nphys1863 (2010)

Although quantum dots (QDs) have great advantages for the fast coherent manipulation of exciton qubits, the interaction between individual QDs is weak. Danny Kim and co-workers from the Naval Research Laboratory in the USA have now demonstrated two-qubit gates with an interaction rate of 30 GHz — more than an order of magnitude faster than that of any other system so far — by exploiting the kinetic exchange interaction that occurs when electrons coherently tunnel between QDs. The team placed a 9 nm GaAs/AlGaAs/GaAs barrier between two vertically stacked InAs QDs such that the electrons could coherently tunnel across it. The QDs were then incorporated into a Schottky diode so that each QD could be charged with a single electron by adjusting the voltage bias. Single-qubit gate operation was implemented using 13 ps circularly polarized pulses with a bandwidth of 146 μeV, whereas two-qubit gate operation was implemented using 150 ps pulses at a bandwidth of 12 μeV. The researchers say that the single-qubit gate requires short pulses to ensure that the two QDs do not

SUPERCONTINUUM GENERATION

Flexible control

Opt. Lett. **36,** 160–162 (2011)

Supercontinuum generation — the spectral broadening of a pump pulse to produce a smooth, wide spectral continuum — is useful for applications such as frequency metrology, optical coherence tomography and wavelength-division multiplexing. However, this technique is inherently incoherent and experiences significant pulse-to-pulse amplitude fluctuations, impeding its utility for applications that require measurements of rapid dynamics and non-repetitive transient processes. Although stability can be achieved through precise time-delay tuning and dedicated feedback control, these complex techniques offer little real-time practical control. Kevin Tsia and co-workers from the University of Hong Kong have now developed a simple triggering mechanism that uses extremely weak continuous-wave light (~80 μW) together with 22 W pump pulses in a 50 m highly nonlinear dispersion-shifted fibre to significantly enhance supercontinuum generation and stability. This technique produces bandwidths ~100 nm wider and with a 100-fold power enhancement in the red- and blueshifted spectral regions than those of the untriggered case. It provides active control of supercontinuum power, spectral shape and temporal stability over a wide range of input pump conditions, expanding the possible applications of supercontinuum generation. The team say their technique could easily be extended to a multiwavelength continuous-wave-triggered configuration to further accelerate and enhance the generation of supercontinuum sources.

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have time to interact when a single spin is optical rotated, whereas the two-qubit gate requires pulses that are longer than the interaction time between the two QDs. The fast interaction rate signifies the viability of optically controlled QD spins for use in multiqubit systems.

TERAHERTZ SPECTROSCOPY

Alternative detection

Appl. Phys. Lett. **97,** 251103 (2010)

Terahertz time-domain spectroscopy involves the conversion of a sub-100-fs near-infrared pulse to a single-cycle pulse of terahertz radiation. Gated detection of the terahertz pulse is usually achieved by time-delaying a fraction of the original near-infrared pulse, where the electric field of the terahertz pulse induces a birefringence in a crystal through the linear electro-optic (Pockels) effect. It has recently been shown that it is possible to detect terahertz and mid-infrared radiation that is not synchronized with the probe beam using a balanced photodiode detection scheme. Now, James Lloyd-Hughes and his co-workers in the UK and Switzerland have demonstrated the thermo-optic detection of terahertz radiation from a 3.2 THz quantum cascade laser. They used a balanced photodiode detection scheme with a ZnTe crystal and a pulsed laser beam at 780 nm and compared it with the gated detection of terahertz pulses from a photoconductive emitter. The unsynchronized signal was found to be dependent on the angle of the crystal and the modulation frequency of the quantum cascade laser, indicating a slow thermo-optic effect rather than an ultrafast electro-optic effect. The researchers present a simple model that accounts for the frequency dependence of the unsynchronized differential photodiode signal, and say that further investigation may lead to enhanced detection efficiencies for materials with high thermo-optic coefficients or those with suitable reflective coatings.

OPTICAL ISOLATORS

Small-gain saturation

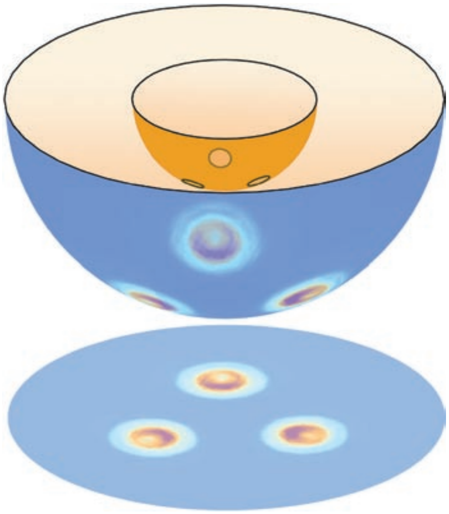
Jpn. J. Appl. Phys. **49,** 122201 (2010)

Integrated semiconductor active optical isolators are attractive for use in photonic integrated circuits. So far, however, the gain saturation effect — a critical factor in determining the propagation loss of such a device — has not been studied. Such optical isolators can only fully compensate for loss if the 3 dB saturation output power P_{3dB} is larger than the practical output power. Hiromasa Shimizu and Syunsuke Goto from the Tokyo University of Agriculture and Technology in Japan have now developed an evanescent semiconductor optical isolator (ESOI) that overcomes the problem of gain saturation. Their ESOI is a 1-mm-long ridge waveguide composed mainly of InGaAsP, with the cross-section of the p-InGaAsP guiding layer measuring 0.8 μm × 2 μm. The researchers covered the lateral side walls of the waveguide with AlO_x/Fe/AlO_x and placed the laser active layer, composed of InGaAsP quantum wells, at the base of the waveguide. Theoretical results predicted that this design would increase P_{3dB} by 6 dB. The researchers measured the propagation characteristics of their ESOI in both the forwards and backwards directions using a tunable laser diode. The ESOI was injected with 1,540 nm light up to 70 mA at a temperature of 10 °C and a permanent magnetic field of 0.33 T. The team obtained an optical isolation of 7.4 dB mm^{-1} and improved gain saturation characteristics over traditional optical isolators.

FAR-FIELD IMAGING

New dimension for hyperlens

Nature Commun. **1,** 143 (2010)



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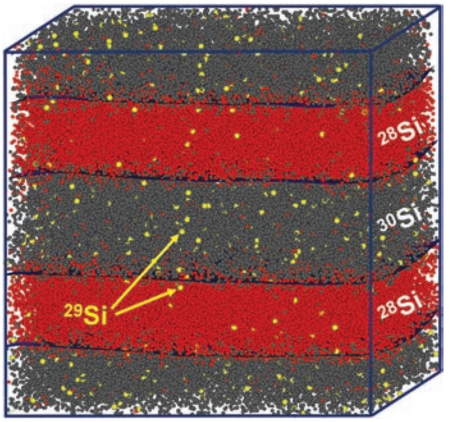
Hyperlenses — focusing devices capable of surpassing the fundamental resolution limit of conventional lenses — have previously been used in only one dimension and at ultraviolet wavelengths. Junsuk Rho and colleagues in the USA have now developed a hyperlens that can resolve 160 nm features in two lateral dimensions at the visible wavelength of 410 nm. The dome-shaped lens consists of alternating layers of titanium oxide, with a dielectric constant of 5.83, and silver, with a permittivity of −4.99 + 0.22i. The lens layers, which are thin compared with the wavelength of light used, form an effective medium that has very different radial and tangential permittivities of −64 − 19.83i and 0.42 − 0.11i, respectively. This difference causes a relative dispersion relation within the hyperlens material, allowing electromagnetic waves that carry high-spatial-resolution details to propagate into the far field instead of evanescently decaying. Such hyperlenses may enable the rapid imaging of nanoscale features in the far field, much like conventional optical microscopy.

TOMOGRAPHY

UV-assisted probe

Appl. Phys. Lett. **98,** 013111 (2011)



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The physical properties of a semiconductor can be drastically changed by the addition of stable isotopes. The key effect is the change in atomic mass, which influences both the lattice dynamics and the bandgap energy. A topographic technique is therefore required to isotopically probe nanoscale structures. Oussama Moutanabbir and co-workers from Germany, the USA and Japan have now achieved 3D isotopic imaging with high spatial resolution using a picosecond UV laser-assisted local-electrode atom probe (UV-LEAP). The wavelength, pulse energy and beam waist of the laser were 355 nm, 40 pJ and <5 μm, respectively. Isotopically modulated ^{28}Si and ^{30}Si ultrathin layers of thickness 5–30 nm were grown by solid-source molecular beam epitaxy. Needle-like specimens with tip radii of 20 nm were fabricated using the focused-ion beam-based lift-out method, after which they were placed in an ultrahigh-vacuum chamber and cooled to 60 K. Concentration depth profiles of the three Si isotopes — ^{28}Si, ^{29}Si and ^{30}Si — were calculated from UV-LEAP tomographic maps. The interfacial width was around 1.7 nm, demonstrating a significant improvement over isotope mapping techniques. The high resolution was attributed to the sharp focusing ability and short penetration depth of the UV laser.

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