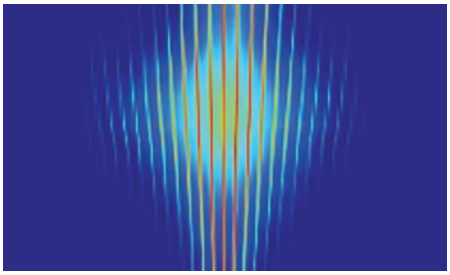
NONLINEAR OPTICS

Realizing Peregrine solitons

Nature Phys. **6,** 790–795 (2010)



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The existence of Peregrine solitons — localized solutions to the nonlinear Schrödinger equation (NLSE) — was predicted by the late Howell Peregrine in 1983 as an explanation for the formation of hydrodynamic rogue waves in the ocean. Having been a theoretical prediction for more than 25 years, these solitons have now finally been observed in a physical system. The experiments carried out by John Dudley and co-workers from France, Ireland, Finland and Australia were based on intense light transmitted in optical fibres, rather than water waves. Their set-up consisted of two external-cavity lasers generating pump and seed signals, an erbium-doped fibre amplifier, a 900-m-long highly nonlinear fibre, an optical spectrum analyser, a frequency-resolved optical gating and an autocorrelator. Rigorous measurements of the ultrafast temporal, spatial and spatiotemporal dynamics of the generated soliton wave were made for different modulation parameters, which could be varied by changing the pump power. The team showed that their results were in very good agreement with numerical simulations and Peregrine's prediction. They are confident that this first observation of Peregrine solitons will help advance the understanding of the formation of rogue waves in the ocean and clarify mysteries in NLSE-based systems from other domains of science.

OPTOFLUIDIC LASERS

DNA-based distance control

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Optofluidic lasers combine the compactness of lab-on-a-chip circuitry with the wide wavelength tunability and spectral coverage of a dye laser. Although such lasers can be optically pumped directly via the dye's absorption band, finding pump sources with a suitable wavelength can be a challenge. A more flexible approach is to use a dye mixture, composed of a donor and an acceptor, and an energy transfer scheme. Now, using DNA scaffolds, Yuze Sun and colleagues from the USA have produced optofluidic dye lasers excited by fluorescence resonance energy transfer (FRET) that have nearly 100% energy transfer. Unlike previous FRET-based optofluidic dye lasers, the energy transfer efficiency of their laser does not depend on the donor and acceptor concentration, which is the averaged donor–acceptor distance. Their trick is to conjugate the donor (Cy3) and acceptor (Cy5) with DNA sequences to maintain the Förster distance between them. The lasers were demonstrated in a thin-walled fused silica capillary whose cross-section formed a ring resonator in which the whispering-gallery modes interacted evanescently with the dye solution flowing through the ring resonator. A pulsed laser at 518.3 nm was used to excite a 1 mm portion of the optofluidic ring resonator capillary. The researchers showed that by using DNA scaffolds, not only the donor–acceptor distance but also their ratio and spatial configuration, and hence the energy transfer efficiency, could be controlled. Nearly 100% energy transfer was obtained and FRET lasing could be achieved at an acceptor concentration as low as 2.5 μM and a lasing threshold on the order of microjoules per square millimetre. The findings seem poised to benefit biochemical sensing and biocontrolled photonics devices.

IMAGING

Thin-film focusing

Biomed. Opt. Express **1,** 762–770 (2010)

Techniques such as Raman and Fourier transform infrared spectroscopy, which can characterize single bacteria within a sample, require high-accuracy position measurements of the bacteria in order to be effective — something that is difficult to achieve with standard complementary metal–oxide–semiconductor sensors. Cédric Allier and co-workers from CEA, France, have now developed a lensless, on-chip imaging system that uses a thin wetting film to focus the illuminating light, thereby achieving a much higher signal-to-noise ratio than previous techniques. The bacteria are first deposited in a 1 μl sample of wetting agent and placed on a glass coverslip. Controlled evaporation is then used to form a thin film of wetting agent over the bacteria, which creates an individual microlens for each object. The researchers achieved a signal-to-noise ratio of 45 ± 10 — considerably higher than the signal-to-noise ratio, of ~2, that pertains when no liquid microlens is used — as well as an overall detection efficiency of 85 ± 7% and a co-localization error of 1.1 μm when compared with reference fluorescence microscopy images. This lensless, on-chip imaging technique offers a cost-effective means of detecting and locating bacteria as small as 1 μm before applying spectroscopic identification methods.

LASER DIODES

Low-threshold green diodes

Appl. Phys. Express **3,** 091201 (2010)

Most green laser diodes are made of group-III-nitride-based materials such as GaN and have the limitation that their threshold current increases drastically when their lasing wavelength is longer than 515 nm. Now Jun-ichi Kasai and co-workers at the AIST, Hitachi and Sony, in Japan, report that BeZnCdSe quantum-well laser diode structures with a short-period superlattice cladding layer can have reduced threshold current in the pure-green spectral region

PHOTOSYNTHESIS

Chlorophyll serendipity

Science **329,** 1318–1319 (2010)

A new form of chlorophyll, the well-known green-coloured pigment that plays a central role in photosynthesis, has been discovered by scientists in Australia and Germany. For the past 60 years, four varieties of the light-harvesting compound have been known. Now Min Chen and co-workers have added a fifth to the list. The new form, dubbed Chl *f*(2), is distinct from the others in that it is optically active at longer wavelengths, with its main absorption and fluorescence peaks lying at 706 nm and 722 nm, respectively, in the near-infrared regime. Chen *et al.* spotted Chl *f*(2) when performing liquid chromatography on a sample of a stromatolite (coastal rock-like structures formed by blue-green algae called cyanobacteria) from the Shark Bay region of Western Australia. The data showed a new, unexpected peak that was deduced by mass spectrometry to be due to $C_{55}H_{70}O_6N_4Mg$. The finding is significant because it shows that photosynthesis can take place with significantly lower-energy photons than previously expected and can operate over a broader range of wavelengths.

at room temperature. The group fabricated the laser diodes on (001) n-GaAs substrate by molecular beam epitaxy. The laser diode structure had a separate confinement heterostructure consisting of a BeZnCdSe single quantum well sandwiched between BeZnSe optical guiding layers. The light output power and forward bias characteristics of an 800-μm-long and 5-μm-wide laser diode were measured under continuous current injection at room temperature. Lasing was observed at 545 nm at a threshold current and voltage of 68 mA and 10.4 V, respectively. This threshold current corresponds to a current density of 1.7 kA cm^{-2}, whereas that obtained in InGaN/GaN quantum-well laser diodes is more than 4 kA cm^{-2}. The researchers pointed out that the lasing wavelength of BeZnCdSe quantum-well laser diodes can be easily shortened in the green spectral range by decreasing the Cd concentration in the active layer.

OPTICAL MATERIALS

All-optical poling

J. Opt. **12,** 095601 (2010)

Periodic poling is a widely used method of optimizing the nonlinear optical performance of the ferroelectric crystal lithium niobate. The approach uses a strong external electric field applied in alternating spatial regions along the crystal to perform ferroelectric domain inversion on a periodic basis. It is an important technique because crystals can be used to perform quasi-phase-matching and have nonlinear effects, such as frequency conversion, that are much more efficient than usual. Now Sakellaris Mailis at the University of Southampton in the UK has shown that an ultraviolet beam of light can be used to perform domain poling, eliminating the need to apply an external electric field by means of electrodes. Mailis's all-optical poling involved irradiating the surface of lithium niobate with the focused beam from either a continuous-wave 244 nm laser or a pulsed 248 nm laser. Chemical etching that is sensitive to the domain orientation of the crystal was then used to determine whether any domain inversion had occurred. The results show that, depending on the polarity of the crystal surface, poling could either induce ($z-$ surface) or inhibit ($z+$ surface) domain inversion. It is suggested that the inversion phenomenon is due to strong local heating induced by the absorbed laser power. Given its simplicity and flexibility — the all-optical poling can be done simply by guiding a laser beam, and does not require electrodes and a high-voltage supply — it is thought that it may be beneficial for making nonlinear-waveguide photonic circuitry.

QUANTUM DOT LASERS

Two-state mode-locking

Appl. Phys. Lett. **97,** 071118 (2010)

Stefan Breuer and co-workers from Germany, Italy, France and the UK have observed stable mode-locking at two different wavelengths simultaneously in a two-section semiconductor laser based on a chirped quantum dot structure. InAs quantum dots were fabricated by molecular beam epitaxy and were embedded in an InGaAs quantum well. To obtain a broad gain spectrum, the quantum dot multilayer was chirped and the In content of the quantum dot was also modified. The emission of light from the active layers was confined by GaAlAs waveguide cladding layers. The ridge-shapes laser consisted of a 3-mm-long gain section and a 0.3-mm-long saturable absorber section. The gain section was pumped with a current source and the absorber section was connected to a voltage source. By applying a reverse bias voltage of 0 V, ground-state mode-locked lasing at 1,270 nm was observed for gain currents above 105 mA, and excited-state mode-locking at 1,207 nm commenced for currents above 130 mA.

ULTRASHORT PULSES

Energy transfer via filaments

Appl. Phys. Lett. **97,** 071108 (2010)

When a laser pulse is sufficiently intense it can form a plasma in air and become a self-guided beam, known as a filament, owing to resulting nonlinear effects. Xuan Yang and colleagues from East China Normal University in Shanghai have used the strong interaction that takes place between two crossed filaments to create temporary plasma gratings (lasting several tens of picoseconds) that can effectively scatter light. In their experiments, an 800 nm, 45 fs pulse from a Ti:Sapphire system was split to form two filaments. One arm of the set-up had a β-barium borate crystal to produce a second harmonic at 400 nm, and the other arm had a half-wave plate and an attenuator to control the polarization and pulse energy. Two lenses with 1 m focal lengths produced the ~5-cm-long filaments in air, with grazing crossing angles variable from 2° to 4°. The plasma fringes are formed around the optical field interferences peaks owing to the local counterbalance of self-focusing, plasma defocusing and higher-order nonlinear effects. Optically, the index is a function of the local plasma density — experiments in which the fluorescence was scattered from nitrogen molecular ions confirmed the plasma grating characteristics. It is hoped that the discovery may be useful in the study of laser–plasma interactions and high-intensity, ultrafast phenomena with all-optical-induced plasma beam couplers.

PLASMONICS

Weighing in

Proc. Natl Acad. Sci. USA **107,** 16028–16032 (2010)

Surface plasmon resonance imaging is a sensitive technique that allows the study of weak concentrations of analytes and even molecular bindings. Now Shaopeng Wang and colleagues from the USA and China have used it for single-virus detection and attogram mass measurement. Excitation of plasmons on a gold surface was achieved using the Kretschman geometry (evanescent coupling through a thin metal film). The required transverse-magnetic polarized light from a 632.8 nm He–Ne laser was fed into an oil-immersed objective with high numerical aperture (1.65). Light passed into the coverslip and decayed through the gold coating. When the angle of incidence was adjusted for phase-matching, resonant excitation of plasmons occurred. Scattering of the surface waves from objects on the surface was then imaged (with a theoretical diffraction limit of 230 nm) using a charge-coupled-device camera. Particle images were even tracked over time, allowing differentiation of various particle–surface interactions. The intensity of scattering is proportional to the volume of the particle. Hence, from the assumed refractive index, $n = 1.48$, and mass density of the virus, as well as the volume–intensity calibration (from silica particles of similar refractive index), the mass of a virus can be determined. The system can detect 13 nm particles corresponding to a mass of 1 ag; in terms of mass per unit area, the limit is 0.2 fg mm^{-2}.