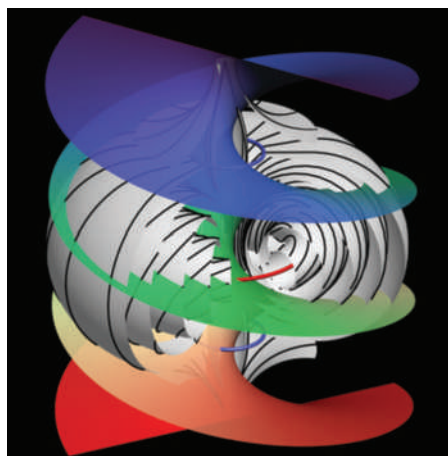


CONDENSED MATTER

All-optical control

Nature Mater. doi:10.1038/nmat2592 (2009)

UNIVERSITY OF COLORADO AT BOULDER



The control of structural organization in matter using light and the manipulation of light using ordered materials are both fascinating fundamental research topics. Now, researchers from the University of Colorado at Boulder, USA, and the Université François Rabelais-CNRS-CEA, France, demonstrate how low-power (10–100 mW) laser beams with phase singularities can be used to control topological singularities in ordered materials. Ivan Smalyukh and colleagues show that by changing the optical phase singularities in Laguerre–Gaussian laser beams they can control and switch 3D multistable twisted structures within liquid crystals. To do this, the researchers use a liquid-crystal spatial light modulator to generate doughnut-shaped Laguerre–Gaussian laser beams that are then focused into untwisted chiral liquid-crystals confined between glass plates. The result is the formation of different types of localized particle-like structures — torons — within the sample. By varying the topological charge of the generated Laguerre–Gaussian beams, the team managed to control the internal structures and topological defects of the torons. “The robustness with which the torons can be generated and switched between multiple distinct states, combined with the diffraction-limited nature of their creation, offers a wide range of applications, including optical data storage, light- or voltage-controlled diffraction gratings and flexible multiple displays,” said Smalyukh.

BOSE-EINSTEIN CONDENSATES

Optical storage

Phys. Rev. Lett. **103**, 233602 (2009)

Bose–Einstein condensate confined in an optical dipole trap can be used to generate an optical long-term coherent memory.

This may help create long-term quantum networks and generate entangled states of light and matter over large distances. Storage times in atomic ensembles are known to be limited by thermal diffusion and loss of atomic coherence resulting from collisions. The trick exploited by Lene Vestergaard Hau and co-workers from Harvard University, USA, is to use optical pulses to separate the phase of an atomic imprint from the main condensate and to control the atomic scattering lengths to minimize inelastic collisions. More specifically, input light pulses transversely localized well below diameters of 80 μm in a Bose–Einstein condensate give rapid phase separation, leading to the formation of localized filled voids. The team were able to control the motions and collisions between these voids through local magnetic field gradients. Storage times of more than 1 s were reported. Thanks to the phase coherence of the condensate and the controlled manipulation of elastic and inelastic atomic scattering processes, storage fidelity was increased by several orders of magnitude.

ULTRAFAST OPTICS

Controlling alignment

Phys. Rev. Lett. **103**, 223002 (2009)

Controlling the orientation of molecules is essential in quantum mechanics for gaining insight into the interactions between anisotropic angular momenta of molecules. Now, Kenta Kitano and co-workers from Japan have proposed an ultrafast (picosecond timescale) control technique that relies on quantum interference between the rotational wavepackets created by two excitation pulses.

To demonstrate the technique, two intense pump pulses at ~ 800 nm were merged and collinearly focused onto jet-cooled benzene ensembles in a molecular beam. The peak intensity for each pulse was a maximum of 1.2 TW cm^{-2} . To break the right- or left-handed symmetry, the second pulse was delayed by a few picoseconds and the polarization was tilted to a certain angle. After excitation by the femtosecond pump pulses, the excitation spectrum of the benzene molecule was probed by a circularly polarized nanosecond pulse at ~ 260 nm. The team observed pronounced intensity changes in the circularity of the probe pulse when the polarization angle of the second pump beam was changed from $\pi/4$ to $-\pi/4$. They numerically solved the time-dependent Schrödinger equation and found that this phenomenon was due to asymmetric distribution of the angular momenta of benzene $\pm M$ sublevels. This technique provides orientated molecular systems that exhibit time evolution in a coherent manner and that can be exploited in broader chemical and physical applications.

PHOTOACOUSTIC IMAGING

Detecting cancer

Nature Nanotech. **4**, 855–860 (2009)

Previous attempts at detecting cancer through the identification of circulating cancer cells (CTCs) in the bloodstream have proven difficult and time-consuming, owing to the large amounts of blood that must be analysed. Now, Ekaterina Galanzha and co-workers have developed an *in vivo* technique for effectively detecting CTCs using magnetic enrichment and photoacoustic imaging.

OPTICAL SENSING

Photonic nose

Adv. Mater. doi:10.1002/adma.200902763 (2009)

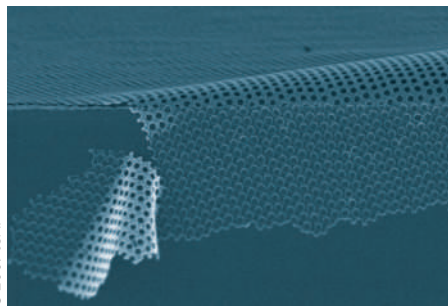
The ability to detect and identify odours (vapour-phase compounds) is crucial for many industries such as pharmaceuticals, food manufacturing and disease diagnostics. Although electrical and gravimetric approaches are available, optical detection techniques that are cheap, simple and environmentally friendly are currently lacking. Researchers in Canada have now developed an elegant solution to this problem. The approach taken by Leonardo Bonifacio and colleagues is based on the optical modulation of Bragg diffraction properties induced by molecules adhered to the surface of a pixelated nanoparticle 1D photonic crystal. The photonic crystal is composed of alternating silicon dioxide and titanium dioxide nanoparticulate layers, known as Bragg stacks. Making the stacks porous creates a ‘photonic nose’ that changes colour when different vapours are adsorbed. In the proof-of-concept experiment, the researchers exposed a 3×3 array to a variety of known alcohols, alkanes and bacteria. A significant degree of discrimination between different alcohols and alkanes was observed, and concentrations as low as a few parts-per-million were detected. Although not all of the tested bacteria were distinguishable, samples that often cause infections in hospitals were discriminated. The team say that the scheme promises a straightforward, low-cost, reusable method for detecting various vapours and that the range of discrimination can be enhanced by introducing further distinct surface functionalities.

The researchers used two nanoparticles that bind to distinct biomarkers to increase the specificity and sensitivity of their diagnostic approach. First, magnetic nanoparticles (MNPs) were altered to bind to urokinase plasminogen activator receptors, which are commonly found in many types of cancer cells. They then introduced golden carbon nanotubes (GNTs), which bind to folate receptors — these are found in cancer cells but not in normal blood. The team found that a wavelength of 639 nm provided the best photoacoustic contrast for MNPs in the bloodstream, whereas GNTs had a higher contrast of 900 nm. After injecting the nanoparticles into breast-cancer-infected mice, the researchers were able to successfully capture the CTC-bound MNPs and GNTs using dual magnetic-photoacoustic flow cytometry technology at these two wavelengths. Through photoacoustic monitoring, they found that the half-life of both the nanoparticles is around 15–20 minutes, and that the number of CTCs detected seems to be correlated to the stage of primary tumour progression as well as vessel size. The team predict that their approach could lead to the early detection of cancer and the prevention of metastasis in humans.

LITHOGRAPHY

Laser thermal patterning

Appl. Phys. Express **2**, 126502 (2009)



© 2009 JSAP

Photoresist lithography may soon be reaching its limit of spatial resolution. Yoshihisa Usami and colleagues from Fujifilm Corporation in Japan have now presented laser thermal lithography, a technique that offers a half-pitch resolution of 40 nm through the use of a 580-nm-diameter focused spot from a 405-nm-wavelength semiconductor laser, combined with a new organic resist material technology. The team engineered an organic resist material that has a higher vaporization temperature (490–570 K) than standard photoresists, and hence decreasing the size of the thermal spot above the threshold for gasification. Fine-resolution lithography with a scale far beyond the optical diffraction limit is possible because the temperature region

above the gasification threshold of the resist is much smaller than the laser spot diameter. For the process to be successful it is important to use a material that does not melt at temperatures below the gasification temperature, otherwise etched shapes will widen. Structures fabricated by the technique were used as dry-etching masks for a number of materials including silicon, silicon dioxide and sapphire, demonstrating the potential for simple high-resolution patterning in a variety of materials.

PHOTONIC CRYSTALS

Tunable lenses

IEEE Photon. Technol. Lett. **22**, 21–23 (2010)

Yonghao Cui and colleagues from the University of Texas at Dallas, USA, have demonstrated thermo-optic tuning of a compact photonic crystal lens operating at a wavelength of 1.55 μm . The lens consists of a 2D silicon crystal measuring only 30 μm \times 7 μm in size, formed by a honeycomb lattice array of silicon rods embedded in silicon dioxide. The structure's anisotropic effective index contour allows it to focus light to a single focal point and therefore function as a lens. The researchers show that by applying localized heating of the photonic crystal structure using a nickel–chromium alloy micro-heater, the refractive index of the silicon can be varied through the thermo-optic effect. The change in refractive index perturbs the photonic band structure and thus modulates the focal length. The team anticipate that this compact and thermo-optically tunable lens will be useful in nanoscale optical imaging applications.

NONLINEAR OPTICS

Pyrolitons

Opt. Express **17**, 22209–22216 (2009)

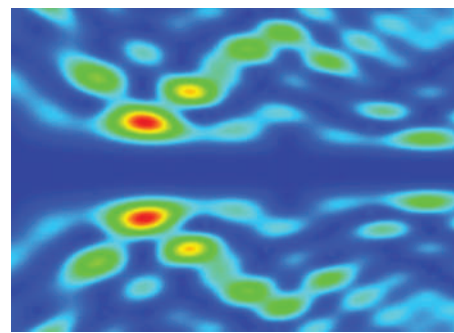
Beam self-trapping is usually observed in Kerr or photorefractive media, and has been a subject of much research. Usually, the phenomenon of light-trapping requires a strong external electromagnetic field. In case of pyroelectric photorefractive crystals, however, such a phenomenon can be induced by a very weak electromagnetic field. Jassem Safioui and co-workers from the Université de Franche-Comté in France have now theoretically and experimentally demonstrated the creation of pyroelectric spatial solitons (pyrolitons) within such crystals. Both undoped photonic-grade congruent and stoichiometric lithium niobate crystals were used. The samples were 8 mm \times 20 mm \times 0.5 mm along x , y and z crystallographic axes, respectively. The sample temperatures were controlled by a Peltier

element. A 532 nm continuous-wave beam was focused onto an 11 μm full-width half-maximum spot at the front face and irradiated onto the z - x plane of the sample with a beam intensity of 80 μW . When the sample was at room temperature, the beam width expanded due to reflections on each side of the crystal. However, when the temperature was raised to 40 $^{\circ}\text{C}$, the expanded beam self-focused to an 8 μm diameter spot after one minute of heating. The researchers are confident that such pyrolitons could be useful for making gratings and 3D integrated circuits.

RACTAL OPTICS

Generalizing the devil

Opt. Express **17**, 21891–21896 (2009)



© 2009 OSA

Researchers in Spain have developed an efficient spiral fractal zone plate called the 'devil's vortex-lens' (DVL), which may prove to be particularly useful for applications such as beam shaping and optical trapping. Fractal zone plates — binary zone plates with a fractal profile that varies with the square of the radial coordinate — are a special form of diffractive optical element that redirects chosen wavelengths of incoming light to a set of predefined positions, creating a focal region with a unique structure. The DVL, proposed by Walter Furlan and co-workers, can generate a sequence of optical vortices surrounding the major foci inside a single main fractal focus, and are useful for microscopic-scale optical trapping with high focal depth. The focal volume provided by such a lens should allow the realization of versatile and efficient optical tweezers that can rotate trapped high-index particles and also trap low-index particles in the zero-intensity region of the focal volume. A traditional 'devil's lens' has a surface relief pattern based on the Cantor function, also known as the 'devil's staircase function'. The DVL developed by the team is a generalization of the devil's lens as it is modulated by a helical phase structure through the introduction of an azimuthal variation in phase. The team say that their DVLs have significantly higher diffraction efficiencies than standard devil's lenses.