QUANTUM IMAGING

Seeing ghosts

Phys. Rev. A **77,** 041801 (2008)

Ghost imaging is an unusual effect in which an image is formed using light that hasn't ever been in contact with the target object. But the issue of whether the effect is quantum mechanical in nature or whether it can be reproduced using classical optics remains unresolved. Ron Meyers and colleagues from the US Army Research Laboratory and the University of Maryland have come up with a ghost-imaging experiment that throws more light, so to speak, on this fascinating phenomenon.

A weak beam of light is divided into two: one part goes directly to a sensitive detector array, whereas the other reflects off the target object and is picked up by a second detector. By comparing the arrival time of photons incident on the two detectors, an image can be formed on the array, even though light hitting the array never interacted directly with the object.

The difference between this experiment and previous investigations into ghost imaging is that it uses scattered and reflected light from the target object rather than transmitted light. The authors say that this result provides evidence against the classical interpretation of ghost imaging and supports the quantum theory. The finding is important not only in terms of providing a better understanding of ghost imaging, but it makes the phenomenon more amenable for implementation in practical applications.

OPTICAL LATTICES

Squeezed light

Opt. Express **16,** 5465–5470 (2008)

Excite a string that has been fixed at the ends, such as on a guitar, and it vibrates in a standing-wave pattern: that is, certain periodically spaced points on the string don't move. The same standing-wave effect can be achieved when two laser beams interfere. Tongcang Li and co-workers at the University of Texas at Austin have now presented a scheme that enables the continuous variation of the period of an optical standing wave.

A single laser beam is separated into two parallel beams using two beam splitters in tandem with a movable mirror. The two beams produce a standing-wave pattern in the focal plane of a lens. The period of the standing wave is dependent on the separation of the beams. The movable mirror provides control over this separation without changing the optical path difference between the two beams. By changing the distance between the beams from approximately 4 mm to 44 mm, the period of the standing wave can be varied from 0.96 μm to 11.2 μm in only a few seconds.

Optical standing waves, or optical lattices, are important in atomic physics: they can be used to trap ultracold atoms. A small period opens up a world of interesting physics, enabling tunnelling of such atoms from one site to the next. However, it makes detection of an individual site quite difficult. The ability to control the period has the potential, so say the authors, of bridging the gap between these two regimes.

NANOPHOTONICS

Peas in a pod

Nano Lett. doi: 10.1021/nl0731567 (2008)

The large surface-to-volume ratio and low structural dimensions of nanowires make them an attractive proposition for photonic devices, such as interconnectors and nanogenerators in future integrated circuits. Chin-Hua Hsieh and co-workers from Taiwan and Japan now unveil a vertical, one-dimensional, ultrafast optical-switch architecture composed of gold nanoparticles embedded in oxide nanowires.

The device is a metal–insulator heterostructure made of two joined Ga_2O_3 nanowires with gold nanoparticles trapped periodically between them — referred to as a 'peapod' nanowire. The peapod nanowire is formed using a reaction between gallium and silica with gold as a catalyst during simple thermal annealing at 800 °C, a process known as vapour–liquid–solid growth.

When excited by light from a Nd:YAG laser with a wavelength of 532 nm, strong photoabsorption is observed with a very quick photoresponse, a maximum photocurrent of over 100 pA and an on/off photocurrent ratio as high as 500. These properties make the nanostructure an interesting option for nanoswitching. The team attributes the fast photoresponse to the pronounced surface-plasmon resonance effects due to the embedded gold nanoparticles. The surface plasmons are generated at the interface of the gold and the Ga_2O_3 by the incident light, and in turn create electrons that can quickly tunnel to an electrode. The researchers are confident that the proposed simple synthetic approach can also be used to create optoelectronic devices with diverse functions, particularly for nanoscale optoelectronics.

OPTOELECTRONICS

Under control

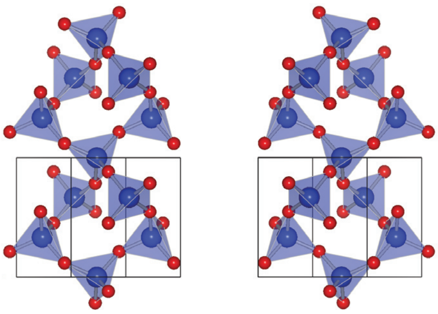
Nano Lett. doi: 10.1021/nl0804809 (2008)

The size of the room-temperature bandgap of the semiconductor zinc oxide makes it an ideal choice for UV optoelectronic devices, such as LEDs and laser diodes. However, because of the low quality of p-doped ZnO, research has focused on devices based on the junction between p-doped GaN and n-doped ZnO, ZnO nanowires in particular. Yet, this too has its problems, most notably visible-light emission from material defects, which limits device efficiency. Also an approach to device fabrication that enables precise control of the location and dimensions of the rods is indispensable if producing uniform devices over large areas is to be the goal. An elegant solution to these problems is provided by Jesse Cole and colleagues from the University of Minnesota, USA: an oxygen plasma treatment used to surface-engineer nucleation areas for the creation of single-crystal ZnO disk structures on a patterned p-doped GaN surface at addressable locations. The researchers implement the method to produce arrays of ZnO microcrystals for LEDs and UV photovoltaic cells.

The technique provides excellent control, yielding heterojunction arrays with uniform geometrical and optical properties. The deep-level defect-related emission in the LED electroluminescence spectra was completely suppressed and a single UV peak could be obtained. With the promising outcome shown in micro-LED and microphotovoltaic cells, the team anticipates seeing more ZnO integrated devices, such as laser cavities and micropower generators.

MATERIAL ANALYSIS

Checking chirality



Phys. Rev. Lett. **100,** 145502 (2008)

Whether an optically active material is left- or right-handed has important consequences on its behaviour, in particular the direction in which it will rotate polarized incident light. Unfortunately, conventional X-ray Bragg diffraction, a popular material analysis technique, is unable to differentiate between the two. However, a Japanese–UK collaboration has now proved that resonant Bragg diffraction, which uses left- and right-circularly polarized (LCP and RCP) X-ray beams, can offer an answer. The team from the RIKEN Spring-8 Center, Japan Synchrotron Radiation Research Institute and Rutherford Appleton Laboratory used their technique to study the so-called forbidden reflection of alpha-quartz, which comes in both left- and right-handed forms. The results show that the different types of quartz generate significantly different intensity-versus-angle data for LCP and RCP X-ray beams, thus allowing the chirality of the quartz to be identified. The experiments were performed at the Spring-8 facility in Harima, Japan, and used a beam energy of around 1,850 eV. In the future the researchers are confident that the technique will prove useful for studying the chirality of other materials, including biomaterials, liquid crystals and multiferroics.

QUANTUM INFORMATION

Flipping spin

Science **320,** 349–352 (2008)

The ability to quickly change the spin of a single electron is important for applications in quantum information processing where spin represents digital data (so-called qubits). Although electronic control schemes provide spin manipulation on nanosecond timescales, scientists would like to have even faster control. The answer may lie with coherent optical manipulation techniques, according to scientists from the Center for Spintronics and Quantum Computation at the University of California at Santa Barbara. Jesse Berezovsky and colleagues have now demonstrated that thanks to the optical Stark effect, ultrashort light pulses can rotate the spin of a single electron in a GaAs quantum dot. According to the researchers, arbitrary rotations of up to 180° (a qubit flip) are possible on a picosecond timescale, and the size of the rotation is determined by the intensity of the light pulse. Although their current set-up potentially allows up to 200 qubit flips within a spin coherence time of 6 ns, the researchers are of the opinion that this could be extended to tens of thousands by using 100-fs-duration light pulses from a mode-locked laser. They also comment that their technique may be useful for obtaining spin echoes, offering a route to extending the spin coherence times.

OPTICAL TWEEZERS

Taking a dip

Appl. Phys. Lett. **92,** 151101 (2008)

Scientists based in the USA and Austria report a new type of optoelectronic tweezers that uses floating electrodes. Their tweezers can drive the movement of water drops through an immersion of oil.

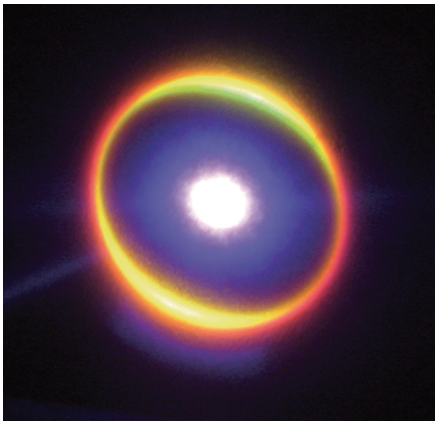
The device is known as floating-electrode optoelectronic tweezers (FEOET). The FEOET consist of a glass substrate onto which are deposited two Si:H layers (one doped, one undoped). Two aluminium electrodes are deposited onto opposite edges of the device and separated by a 1-cm gap. An open polydimethylsiloxane (PDMS) chamber houses the aqueous drops that are immersed in oil.

A d.c. bias is applied to the two electrodes to create a lateral electric field across the whole device. When light is shone onto the undoped Si:H layer, electron–hole pairs are created. This changes the local photoconductivity and disturbs the electric field near the illuminated region. The perturbed field penetrates the oil, generating dielectrophoretic forces that can then move the water droplets away from the light.

Using this technique, Sungyong Park and co-workers show that a 681-μm-sized water droplet immersed in corn oil can be actuated with a 3.21-μW laser beam, at a maximum speed of 85.1 μm s^{-1}. The FEOET could offer a useful platform for massively parallel droplet manipulation with optical images in a low-cost package.

ALL-OPTICAL SWITCHING

Single-photon power



Appl. Phys. Lett. **92,** 151109 (2008)

All-optical switching has the potential to offer ultrafast switching speeds that are not subject to conventional electronic limitations, and could help revolutionize communication and information processing. Researchers in China have now demonstrated an all-optical switch based on three-wave-mixing parametric amplification in a nonlinear crystal.

The idea underlying the scheme involves using a weak beam of light to turn a stronger beam of light on and off. This is essential for cascaded classical and quantum computation elements. Although the concept has already been demonstrated using four-wave mixing, Xiao-Feng Han and colleagues present an approach based on three-wave-mixing optical parametric amplification in a nonlinear crystal. Using a beta barium borate crystal as the core switching element, they show that a beam containing single photons (with an average of 0.75 photons per pulse) can be used to turn a beam containing up to 5.9 × 10^8 photons on and off. The switching can be performed within 400 fs. Analysis of the on/off states shows that they are well defined and that the switch has a broad bandwidth of 10 nm (or 5 THz).