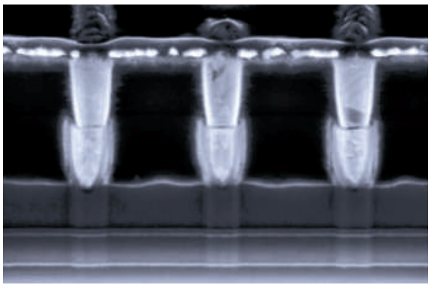
AVALANCHE PHOTODETECTOR

## Germanium amplification

*Nature* **464,** 80–84 (2010)



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It is likely that future high-performance computer systems will require optical communication circuits to be integrated directly into microprocessor chips. This will require photodetectors that can detect very low levels of light at high speed, and germanium avalanche photodetectors (APDs) are potential candidates for such a device, owing to their high gain. However, germanium APDs traditionally suffer from intolerably high amplification noise, which prohibits their use for such applications. Now, Solomon Assefa and co-workers at the IBM Thomas J. Watson Research Center in New York have demonstrated that applying a strong non-uniform electric field to the germanium amplification layer of a germanium APD can reduce the amplification noise by 70%. The applied electric field reduces the region of impact ionization in germanium to only 30 nm, allowing the device to benefit from the noise-reduction effects that arise at such small distances. High-gain, low-noise germanium APDs have already been developed, but these have intrinsically low speeds of around 10 GHz and require bias voltages above 25 V. In contrast, the APD developed by Assefa and colleagues operates at around 30 GHz with a bias voltage of only 1.5 V, and achieves an avalanche gain of over 10 dB. Such a device is expected to find applications in many areas beyond computer optical interconnects, including in telecommunications, quantum key distribution and subthreshold ultralow-power transistors.

GRAPHENE

## Generating ballistic currents

*Nano Lett.* **10,** 1293–1296 (2010)

Graphene's ability to support ballistic currents is attractive for many applications, including graphene-based spintronics and quantum computing. However, injecting and detecting ballistic currents in graphene remains a major challenge, and is inhibiting many of its potential applications. Dong Sun and co-workers in the USA and Canada have now shown that the quantum interference between two phase-controlled cross-polarized pulses can be used to generate ballistic electrical currents in unbiased epitaxial graphene at 300 K. The team use a 250 kHz Ti:Sapphire oscillator/amplifier and an optical parametric amplifier to produce a train of pulses that are then passed through a frequency-doubling crystal, producing a second-harmonic beam that is collinearly propagating with the fundamental beam. The ballistic current amplitude is determined by the relative phase between the pulses, and the team control this by passing the two beams through a $CaF_2$ plate with tunable tilt angle. Furthermore, the structural symmetry of graphene allows the injected current direction to be controlled simply through the polarization of the pump beams. The researchers detected coherently radiated terahertz pulses in the far field, which were used to determine the injected currents. Such a control scheme provides an all-optical, non-contact way of injecting directional current in graphene, and provides new insights into the optical and transport process in epitaxial graphene.

QUANTUM OPTICS

## Photon-pair source

*Phys. Rev. A* **81,** 031801(R) (2010)

Photon-pair sources are important for quantum information processes. Spontaneous parametric down-conversion in nonlinear crystals and spontaneous four-wave mixing in fibres have been used to generate photon pairs either in the region of 600–900 nm or at telecommunications wavelengths (~1.5 μm). Now, Christoph Söller and co-workers from Max Planck Institute for the Science of Light, Germany, have presented a photon-pair source that bridges the visible and telecommunications wavelength regions. Their source is based on four-wave mixing in a solid-core photonic crystal fibre (PCF). Ti:Sapphire femtosecond pump pulses were launched into a 65-cm-long PCF whose hole-to-hole distance and hole diameter were 1.2 μm and 0.7 μm, respectively. Through a $\chi^{(3)}$ nonlinear optical effect, signal and idler waves were generated in the PCF. The team observed that, at a pump wavelength of 771 nm, the group velocities of idler and pump signals were matched, leading to the generation of spectrally decorrelated photon pairs with the signal at 513.5 nm and the idler at 1,547 nm. Analysis suggests a photon purity of up to 82%, implying that the generation of heralded broadband ultrafast single-photon wavepackets is possible at telecommunications wavelengths.

COMPLEX MEDIA

## Transmission matrix clout

*Phys. Rev. Lett.* **104,** 100601 (2010)

The transmission matrix is a mathematical tool that provides the ability to calculate light transport through a medium. However, it is challenging to construct such a matrix for a medium with anything except the simplest geometries. Experimentally determining the required values in the matrix for complex media is also elusive in the optical domain because

LIQUID CRYSTALS

## Soliton logic

*Appl. Phys. Lett.* **96,** 071104 (2010)

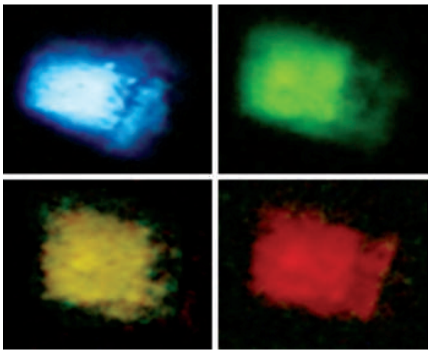
The ability to control the propagation of spatial solitons all-optically could prove useful for creating reconfigurable optical interconnects or logic gates in the future. Now, Armando Piccardi and co-workers from Italy and France have designed a light valve that offers low-power, point-wise control for such solitons. The light valve is formed from a layer of nematic liquid crystal sandwiched between a slab of a transparent photoconductive crystal (bismuth silicate) and a glass substrate. A bias voltage is applied across the light valve, controlling the optical properties of the liquid crystal. Upon external illumination with a laser spot with a power of only a few milliwatts, the resistivity and voltage of the bismuth silicate slab can be locally controlled. This in turn locally modifies the optical properties of nematic liquid crystal beneath, causing a deviation in the path of the soliton. By exploiting the selectivity of the localized perturbation, the team realize basic logic gates, such as NOR, XNOR and Boolean half-adder, through the use of a spatial light modulator that defines and switches several control spots on the bismuth silicate. This scheme shows promise for digital or analogue switching and gating operations for signal processing.

of the need to measure amplitude and phase. Sébastien Popoff and colleagues at the École Supérieure de Physique et de Chimie Industrielles (ESPCI) in France have now experimentally measured the transmission matrix of a random multiple-scattering medium at visible wavelengths. To access the complex optical field, the team used a spatial light modulator and interference with a well-known reference wavefront. A 532 nm laser source was first expanded, then spatially modulated before illuminating a ZnO sample with a thickness of about 80 µm on a microscope slide, and the output speckle was imaged using a CCD. With the matrix known, a host of applications are possible. For example, one can focus to a spot through the complex media, as the group experimentally demonstrated, or inversely detect amplitude and phase at an object placed near the scattering sample.

NANOCRYSTALS

## Broad and stable emission

*Nano Lett.* **10,** 1466–1471 (2010)



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Luminescence from solid films is potentially useful for display technology and other applications. Unfortunately, tunable blue light emission in cubic silicon carbide nanocrystal films has been hampered by complicated surface chemical disorder and the presence of amorphous material. Now, Paul Chu and colleagues from China have successfully demonstrated tunable, broad and stable violet to blue-green emission in such nanocrystal films bonded using glycerol. It is believed that the glycerol-bonding prevents the formation of non-radiative defects and surface states. The result is a quasi-continuous band in the conduction band, in contrast with the isolated levels found in bare nanocrystals, providing continuously tunable light emission. The possibility of photoluminescence from the glycerol itself was ruled out by measuring the emission from pure glycerol excited at the wavelength of interest. As an application, the team coated the glycerol-passivated cubic silicon carbide onto porous silicon and obtained strong photoluminescence tunable within the entire visible range (360–760 nm) by changing the incident wavelength.

HIGH HARMONIC GENERATION

## Tunable enhancement

*Phys. Rev. Lett.* **104,** 073901 (2010)

Although the generation of coherent light in extreme-ultraviolet and X-ray regions by high harmonic generation (HHG) has been extensively studied, its applications have been hindered by the low efficiency of the HHG process, which is due to the difficulty of phase matching. Carles Serrat and Jens Biegert from Spain have now reported a method that can generate short-wavelength coherent light without such a limitation. The approach is based on exploiting a static periodic electric field (created by interferometry with a $CO_2$ laser) in a neon gas. The period of the static electric field is parallel to the propagation direction of a fundamental driving laser beam. In the calculation, the team considered an 800 nm linearly polarized laser pulse with pulse width of 5 fs, diameter of 40 µm and peak intensity at focus of $7 \times 10^{14}$ W cm$^{-2}$. The simulated spectral power showed that 93–99th harmonic waves near 140–160 eV were enhanced with respect to those without the static electric field. The enhanced region of HHG could be controlled by means of the period of the static electric field. The enhancement was also sensitive to the carrier–envelope phase of the generated harmonics. An enhanced coherent radiation of more than two orders of magnitude in the X-ray region was reported in the presence of a static electric field as weak as 1.12 MV cm$^{-1}$.

PHOTOACOUSTIC IMAGING

## Tone burst excitation

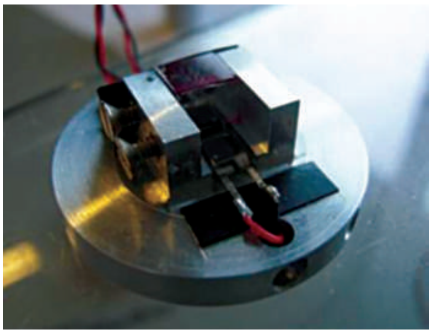
*Opt. Express* **18,** 4212–4221 (2010)

Photoacoustic imaging has recently garnered much attention as it offers high optical contrast and spatial resolution, making it ideal for a number of biomedical applications, including blood flow analysis. Now, Adi Sheinfeld and colleagues from Tel-Aviv University in Israel have extended the application of photoacoustic imaging to measure flow and particle position based on the Doppler effect using tone burst excitation. The use of burst excitation allows the researchers to simultaneously obtain information on the spatial positions of the particles as well as their velocities, an important benefit. The researchers used heterodyne detection to measure the flow rate of a suspension of carbon particles in a 3 mm transparent silicon tube. The technique was able to measure data for mean particle velocities of up to 130 mm s$^{-1}$, over 10 times as high as the capability of previously reported photoacoustic Doppler apparatus. The team predicts that their method should extend to even higher velocities in the future.

BIOPHOTONICS

## Monitoring heart rate

*Opt. Express* **18,** 4867–4875 (2010)



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Doctors often rely on a diagnostic technique known as photoplethysmography (PPG) for continuous monitoring of vital signs such as heart rate and blood oxygenation in patients. In most cases, contact PPG — in which sensors and light sources are in contact with the skin — is a suitable option. However, this technique is not ideal in situations where patients suffer from sensitive or damaged skin, or where movement is unavoidable. Now, Giovanni Cennini and co-workers from the Netherlands, France and Germany have developed a device that efficiently monitors heart rate in real time through remote PPG, while reducing any motion artefacts in the signal. The researchers were able to collect light signals using a compound parabolic concentrator and two photodiodes with associated wavelength filters. Two separate signals were obtained through a dual-wavelength illumination technique: the PPG signal containing motion artefacts (obtained with blue light) and a signal proportional to the motion of the skin (obtained with infrared light). The heart-cycled component of the PPG signal was then amplified, and an adaptive echo cancellation algorithm was implemented to subtract the motion-caused irregularities from the PPG signal, allowing for an accurate heart rate calculation. The team expects that this dual-wavelength technique will be applied in all future efforts in developing remote PPG.