GRAPHENE

High photoresponsivity

Nat. Commun. **4,** 1811 (2013)

Conventional field-effect-transistor-based graphene photodetectors suffer from poor responsitivity (<10 mA W^{-1}) owing to low absorption in monolayer graphene and the short recombination lifetime of the photogenerated carriers. Now, by employing bandgap engineering in graphene, Yongzhe Zhang and colleagues from Singapore and China have developed a device with a much improved performance of 8.61 A W^{-1} — around three orders of magnitude higher than that of previous devices. The researchers report that their graphene photodetector, as well as being highly sensitive, also has a very broad photoresponse spanning from the visible (532 nm) to the mid-infrared (~10 μm). The team introduced a bandgap and a defect mid-gap states band (MGB) by fabricating a structure that resembled an array of graphene quantum dots. Defect MGB electron-trapping centres then formed on the boundary and surface of the graphene quantum dots, thus creating a bandgap due to quantum confinement. The team attributed the large and broad photoresponse to electron trapping in the defect MGB, which was enhanced by carrier impact ionization. The proposed approach is compatible with CMOS technology. Although the operating speed of their device was low, the researchers say that this could be overcome by defect and nanostructure engineering to decrease the trapped electron lifetime in graphene. *RW*

QUANTUM INFORMATION

Single-ion readout

Nature **497,** 91–95 (2013)

Measuring the electron spins associated with single defects in solids is a critical task in the field of quantum information processing. However, it is difficult to achieve the required high fidelities with the two material systems usually employed — phosphorus dopants in silicon and nitrogen–vacancy centres in diamond. Now, Chunming Yin and co-workers from the University of New South Wales, the University of Melbourne and the Australian National University in Australia have demonstrated a hybrid optical–electrical readout technique to overcome these drawbacks. The researchers used a single-electron transistor, which works as a charge sensor, to investigate the charge state of single erbium ions (Er^{3+}) implanted in silicon. First, they cooled the Er-implanted single-electron transistor to 4.2 K. They then tuned the wavelength of the excited beam to the resonant wavelength of the $^4I_{15/2}$–$^4I_{13/2}$ transition of Er^{3+}, which allowed the charge displacement induced by an ionization event to change the tunnelling current of the single-electron transistor. This permitted real-time observation of the charge state of an Er defect centre in silicon, thus avoiding the bottleneck of photon collection. When the researchers applied a magnetic field to the single-electron transistor, they observed eight resonant peaks, with a photon energy difference of around 0.2 μeV. This approach avoids the thermal broadening limitation of an all-electrical readout scheme and has potential for the single-shot readout and manipulation of nuclear spin states. *NH*

DYE LASERS

Going solvent-free

Opt. Express. **21,** 11368–11375 (2013)

Optofluidic dye lasers, although attractive as miniature coherent light sources for integrated optics, unfortunately require a solvent for the preparation of their liquid dye solution. To fabricate such a laser without a solvent, Eun Young Choi and co-workers from South Korea and France used a liquid organic semiconducting material — liquid carbazole (9-(2-ethylhexyl)carbazole) — as the gain medium. They doped the liquid with green- and red-emitting laser dyes and incorporated it into two different laser geometries: waveguide and Fabry–Pérot microcavity lasers. The researchers observed amplified spontaneous emission and lasing when optically pumping the devices using ultraviolet light (355 nm) from the third harmonic of an Nd:YAG laser. This emission is thought to be due to cascaded Förster-type energy transfer from the liquid carbazole to the laser dyes. The emission wavelength could be tuned by using different liquid blends. In the case of liquid carbazole doped with green dyes in a Fabry–Pérot cavity, the laser thresholds were as low as 33 μJ cm^{-2} and 19 μJ cm^{-2} for emission wavelengths of 512 nm and 526 nm, respectively. This is comparable to the performance of organic solid-state dye lasers. The researchers anticipate that new liquid organic optoelectronics applications should be possible by using these tunable solvent-free fluidic organic lasers. *RW*

RYDBERG STATES

Surprising stability

Phys. Rev. Lett. **110,** 203002 (2013)

Using a strong laser field to probe an atom often causes the atom to become photo-ionized. Ulrich Eichmann and colleagues in Germany have now shown that atoms in Rydberg states are exceptionally stable in strong laser fields. Rydberg atoms — excited states that are described as being 'hydrogen-

OPTICAL MATERIALS

Thin photovoltaics

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Semiconducting transition metal dichalcogenides (TMDC) — commonly used as solid-state lubricants and industrial surface coatings — are also being considered for photovoltaic applications owing to their strong optical absorption. It is hoped that such applications could lead to the development of very-thin-film solar cells. However, a major difficulty for their photovoltaic use lies in efficiently separating photogenerated electron–hole pairs within such materials. Liam Britnell from the UK and an international team of co-workers have now demonstrated a possible solution. The researchers placed the photoactive TMDC layer in a stack between two graphene layers and then doped the two layers in different ways to position Fermi levels and enable photocurrent extraction. They used hexagonal boron nitride as the substrate and encapsulating layer, and tungsten sulphide as the TMDC. They note, however, that their results could be generalized to cover other TMDCs. The researchers used flexible photovoltaic devices with an external quantum efficiency of 30%. The layered structure and mechanical strength of graphene and TMDC crystals were also beneficial. *DP*