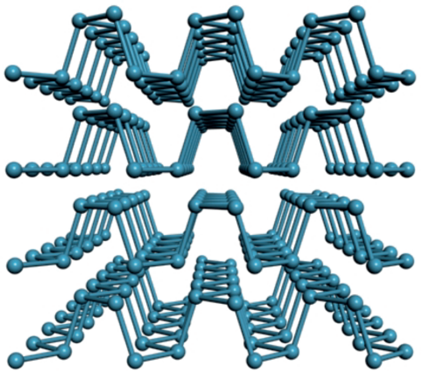
2D MATERIALS

Multilayer black phosphorus

Nano Lett. **16,** 1683–1689 (2016)



AMERICAN CHEMICAL SOCIETY

Mid-infrared light in the 2–10 μm wavelength range is useful for applications ranging from molecular spectroscopy to guided missile technology. However, the realization of a chip-integrated modulator operating in the mid-infrared regime remains challenging. Now, Charles Lin and colleagues from the University of Toronto, Canada and the University of Minnesota, US, propose, based on theoretical analysis, that a modulator formed from a multilayered black phosphorus thin-film on top of a silicon nanowire may be a viable option. The modulator is formed by a Si waveguide approximately 1,000 nm wide and 310 nm thick, covered by a black phosphorus film and then an Al_2O_3 passivation layer, and designed for operation at 2.1 μm. An alternative proposal for 3.3-μm-wavelength operation considers a 1,340-nm-wide and 500-nm-thick wire. Various black phosphorus thicknesses were investigated, for example, 6 nm (2.1 μm wavelength) and 20 nm (3.3 μm wavelength). A figure-of-merit, based on extinction ratio divided by insertion loss, yields a value of 5.5 from a single black phosphorus quantum well, compared with 1.6–4 from SiGe modulators (with >10 quantum wells). The researchers also showed that the optical bandgap can be blue-, red-, or bidirectionally-shifted if an out-of-plane electric field is applied. *DP*

LIGHT–MATTER INTERACTIONS

Superconducting gain

New J. Phys. **18,** 023019 (2016)

Could superconductors turn out to be useful for building new types of photonic device? According to calculations performed by scientists in Israel, hybrid semiconductor–superconductor structures could, in theory, provide enhanced ultrafast two-photon gain (TPG). Raja Marjieh and collaborators from Technion have developed a theoretical quantum description of the ultrafast light–matter interaction in an electrically driven semiconductor–superconductor structure. They studied a structure that resembles an edge-emitting p–n junction laser diode made from an n-type ridge on top of a p-type substrate, but with the important innovation that the ridge is capped with a thin layer of superconductor. Their analysis focuses on TPG in the superconducting proximity region of the semiconductor for an ultrafast light pulse that is propagating along the direction of the ridge. Interestingly, the expressions for the two-photon emission exhibit interference terms between different two-photon transition paths corresponding to distinct spectral components of the ultrafast pulse: this indicates the possibility to realize coherent control of TPG. Further, the researchers evaluate the enhancement of TPG due to the presence of the superconductor by taking into account one-photon gain and loss. They find that an increase in the carrier density leads to a broader TPG spectrum, and that for moderately high seed intensities the TPG becomes comparable to one-photon gain. *GD*

SENSORS

Temperature sensitivity boost

Appl. Phys. Lett. **108,** 061902 (2016)

Optical temperature sensing based on making fluorescence intensity ratio measurements of two thermally linked transitions in rare-earth-doped materials is now a well-established concept. However, to date, the sensitivity of the approach has been a limitation. Researchers from Harbin Institute of Technology in China now report that the sensitivity of the approach can be dramatically improved by employing ferroelectric Pr^{3+}-doped $(K_{0.5}Na_{0.5})NbO_3$ (also known as KNN:Pr^{3+}) as a sensing medium. The team achieve an ultrahigh sensitivity of $7{,}997/T^2$, the highest value achieved so far and more than twice that of earlier work, by measuring the intensity ratio of the $^1D_2$–$^3H_4$ (603 nm) and $^3P_0$–$^3H_4$ (489 nm) transitions under excitation with 325 nm ultraviolet light. Photoluminescence measurements made between 293 and 456 K confirm the validity of the approach. *OG*

OPTOELECTRICAL COOLING

Molecules go submillikelvin

Phys. Rev. Lett. **116,** 063005 (2016)

While laser cooling is a well-established technique to produce atoms at very low temperatures, researchers have lacked an analogously robust and versatile approach for cooling molecules. The capability to cool molecules would advance investigations in fundamental physics and spectroscopy. Now, Alexander Prehn and co-workers from Germany have developed a scheme to cool molecules of gaseous formaldehyde down to microkelvin temperatures. Their approach is based on optoelectrical Sisyphus cooling, which involves a combination of laser, microwave and radiofrequency sources and an electrostatic trap. The molecules lose kinetic energy in a closed cooling cycle that promotes them to strongly trapped rotational states first, and then lowers them to states with weaker Stark interaction in the strong-field region at the edges of the trap. The researchers report the production of an ensemble of approximately 3×10^5 cooled molecules with a temperature of about 420 μK. Moreover, more than 80% of the ensemble populates a single rotational state. When compared with an uncooled sample, these results indicate a reduction of kinetic energy by a factor of 1,000. *GD*

METROLOGY

Seebeck analysis

Phys. Rev. Appl. **5,** 024005 (2016)

An all-optical, contactless scheme for measuring the Seebeck coefficient in a semiconductor advantageously offers high spatial resolution and avoids material or electrical artefacts that can be encountered in other measurement schemes. The Seebeck effect, whereby an electrical voltage is generated due to a temperature gradient in a material, is employed to construct thermopiles and thermoelectric generators. The strength of the effect is material dependent and determined by a material's Seebeck coefficient. François Gibelli and co-workers have now developed an optical measurement scheme and successfully applied it to a multi-quantum-well semiconductor structure with wells made from $In_{0.78}Ga_{0.22}As_{0.81}P_{0.19}$ and barriers from $In_{0.8}Ga_{0.2}As_{0.44}P_{0.56}$. The sample is excited with 980-nm light from a continuous-wave single-mode laser and photoluminescence images captured across the 600 to 1,700 nm wavelength band. Analysis of these spectral images can be used to determine the sample's electrochemical potential and temperature gradient and thus the Seebeck coefficient. *OG*

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