A graphene-based digital camera

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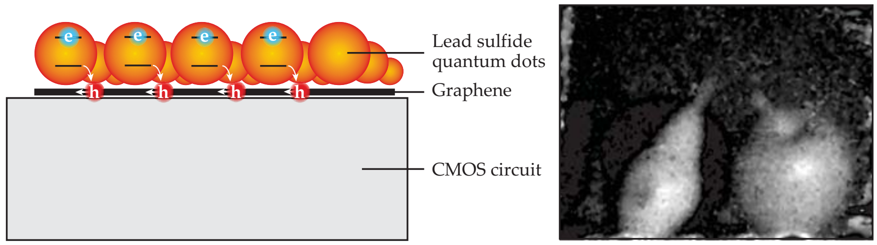
A GRAPHENE-BASED DIGITAL CAMERA

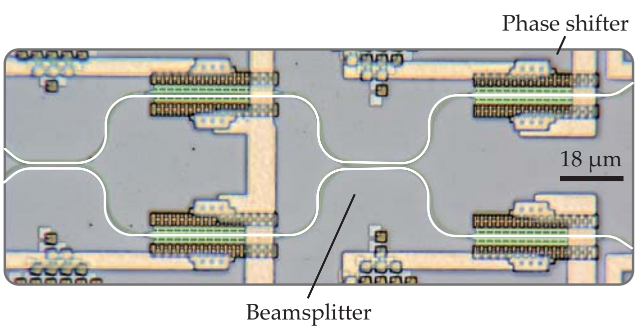
At the heart of a smartphone camera is CMOS circuitry that registers the electrons produced when visible light strikes a silicon wafer. Other semiconductors coupled to CMOS circuits could enable cameras to image in the UV, IR, and terahertz bands; such detectors could see applications for night vision, food inspection, environmental monitoring, and more. Now a research team led by Gerasimos Konstantatos and Frank Koppens of the Institute of Photonic Sciences (ICFO) in Barcelona, Spain, has taken the first steps toward that possible future: It has coupled a graphene–quantum dot photodetector to a CMOS circuit to create an imaging chip sensitive to wavelengths ranging from 300 nm to 1850 nm. (The group's earlier related work was discussed in PHYSICS TODAY, July 2012, page 15.)



The researchers' device, whose surface is roughly 15 mm × 15 mm, has almost 120 000 active pixels, plus a row of insensitive "blind" pixels. The left side of the figure shows a side-view schematic of a single pixel. A graphene layer lies atop the CMOS; the photosensitive material, lead sulfide quantum dots, is deposited on the graphene. When light hits a PbS quantum dot it creates electron–hole (e–h) pairs. The holes enter the graphene layer, where they flow due to a voltage applied across each pixel. The device measures light intensity by comparing the current in an active pixel with that in the blind pixels. The right side of the figure shows the result: a view of a pear and apple illuminated with IR light. (S. Goossens et al., *Nat. Photonics* **11**, 366, 2017.) —SKB

A DEEP NEURAL NETWORK OF LIGHT

Our brain's neurons are, in essence, living logic gates: They take averages of the signals they receive from their neighbors and, depending on the results, either fire or don't. In artificial neural networks, that process is replicated using matrix multiplication, but the task can be time and energy intensive. Now a study by Marin Soljačić, Dirk Englund (both at MIT), and colleagues has demonstrated that the matrix operations underlying neural network computing can be performed quickly and efficiently using photonic circuits. The team's circuits exploit micron-sized beamsplitters and programmable phase shifters to manipulate input signals from an array of neurons and compute the values that determine neuronal responses. Couplings between waveguides can be adjusted to mimic how neuronal connections strengthen and weaken during real learning. (The image shows some of the circuit's elements.)



The researchers used the photonic circuits to build a deep neural network—one comprising several layers of artificial neurons—and trained it to recognize simple speech. After exposure to 180 recordings of four different vowel sounds spoken in a variety of voices, the neural network correctly classified subsequent clips of the vowel sounds more than 75% of the time. That accuracy should improve as the team incorporates more neurons into the network. The proof-of-concept network had just four per layer, but state-of-the-art nanofabrication techniques should allow thousands. As of now, the researchers' network still relies on conventional electronics to simulate neuronal firing. But if that step can be implemented optically—say, with nonlinear dyes or semiconductors—only the training stage will require electronics. Once trained, the network would then be able to perform calculations two orders of magnitude faster than its fully electronic counterparts. (Y. Shen et al., *Nat. Photonics* **11**, 441, 2017.) —AGS

WEIGHING A STAR WITH LIGHT

Einstein's general theory of relativity, first proposed more than a century ago, predicts that in the gravitational field of a massive body, light rays should bend by an angle that depends on the body's mass. Researchers at the Space Telescope Science Institute have now exploited that effect, known as gravitational lensing, to determine the mass of a star. For two years, the team tracked white dwarf Stein 2051 B as it crossed in front of a distant background star. At their closest, the stars were separated by a mere 10th of an arcsecond—roughly the angle subtended in the sky by Pluto.

As the stars came into alignment, gravitational lensing by the white dwarf subtly distorted the apparent position of the background star. Specifically, the background star appeared to trace an ellipse a couple of milliarcseconds wide, even though its actual position in the sky all but remained fixed. (The illusion, exaggerated for illustrative purposes, is depicted in the video in the online version of this story.) From the ellipse's dimensions the researchers could infer Stein 2051 B's mass, roughly two-thirds that of the Sun. The new result agrees with astrophysical models of white dwarfs and may help settle a long-running discrepancy. Previous analyses based on estimates of the orbital motion of Stein 2051 B and its binary companion had suggested—erroneously, it now seems—that the star was much lighter. The new study marks the first time that apparent shifts in the position of a star due to gravitational lensing have been used to determine the mass of a body outside our solar system. (K. C. Sahu et al., *Science* **356**, 1046, 2017.) —AGS PT