PHYSICS UPDATE

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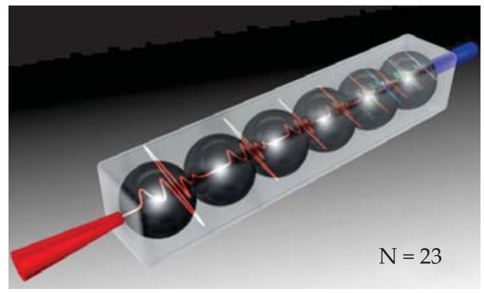
A GRANULAR ACOUSTIC DIODE

Diodes, which allow electricity to flow in only one direction, have been the key to the development of modern electronics. Creating acoustic analogues that restrict sound transmission to one direction has proven challenging. In no small part that's because wave propagation is inherently symmetric: A system's transmission is unchanged if the source and detector are reversed (see PHYSICS TODAY, May 2016, page 14). There have been some successes in creating acoustic diodes, transistors, and logic elements, but most have relied on nonlinear media that distort the waveforms. Now Tianzhi Yang (Tianjin University) and Jian-Guo Cui and Li-Qun Chen (Shanghai University) demonstrate a simple, nondispersive system for nonreciprocal acoustic propagation: a one-dimensional chain of 23 beads. The flexibility to select the number, shape, stiffness, and arrangement of the component elements in such granular crystals facilitates the tailored engineering of their behavior. (See the article by Mason Porter, Panayotis Kevrekidis, and Chiara Daraio, PHYSICS TODAY, November 2015, page 44.) The central feature of the new work is an amplitude-dependent bandgap that arises from the weakly nonlinear contact forces between the 1.6-cm-diameter polypropylene beads. As theoretically predicted in 2015, a tapered rod (red in the schematic) placed at one end of the chain will amplify acoustic waves incident from that side and allow them to surmount the bandgap and pass through with little distortion. But waves traveling in the reverse direction don't get that boost; instead, they get significantly attenuated. The acoustic diode's operating frequency, about 1400 Hz, falls within the audible range. The readily realized geometry could lend itself to such practical applications as a "one-way sound wall," the acoustic equivalent of a one-way mirror. (J.-G. Cui, T.-Z. Yang, L.-Q. Chen, *Appl. Phys. Lett.* **112**, 181904, 2018.) —RJF



POSITRONS OUTSHINE ELECTRONS

In a process inverse to the photoelectric effect, phosphors and other cathodoluminescent materials emit photons when struck by sufficiently energetic electrons. That process is central to the function of old-style televisions and certain light-emitting diodes, microscopes, and scintillation detectors. But electrons aren't the only particles that can trigger cathodoluminescence—so can their antimatter counterparts, positrons. Now Eve Stenson at the Max Planck Institute for Plasma Physics in Germany and her colleagues report marked differences in the phosphor luminescence produced by positrons and electrons of the same energy.

The researchers directed a beam of positrons with energies between 0 and 5 keV at two phosphor screens and then did the same with an electron beam. CCD cameras captured the light that emerged. For both screens, positrons produced substantially more luminescence than electrons with the same energy. For example, 5 eV positrons striking a zinc oxide phosphor, which was chosen for its low-energy sensitivity, triggered as much luminescence as 2.3 keV electrons.

The findings demonstrate that even sluggish positrons do more than just transfer their kinetic energy to coax photon emission in phosphors. The impinging antimatter particles encounter and annihilate with valence electrons to leave behind positively charged holes. Other electrons in the material then combine with the holes to produce more photons. Exactly how that happens, and how much photon emission results, seems to depend on the properties of the given material. The researchers say that by analyzing the differences between positron- and electron-induced luminescence, condensed-matter physicists could investigate outstanding questions about cathodoluminescent materials, such as why they don't luminesce at all below a certain energy threshold. (E. V. Stenson et al., *Phys. Rev. Lett.* **120**, 147401, 2018.) —AG

IMAGING VORTEX FILAMENTS DURING CARDIAC FIBRILLATION

In ventricular fibrillation, the muscle cells of the heart's two large, lower chambers (the ventricles) lose their synchronization; instead of coordinated pumping action, the cells twitch chaotically. Without immediate medical attention, the condition leads to sudden death. Fibrillation has been connected to the formation of vortex-like spiral waves of electrical activity (see the Quick Study by Andrea Welsh, Edwin Greco, and Flavio Fenton, PHYSICS TODAY, February 2017, page 78, and the articles by Leon Glass, PHYSICS TODAY, August 1996, page 40, and by Alain Karma and Robert Gilmour, March 2007, page 51). Within the heart muscle, spiral waves extend into a three-dimensional analogue called scroll waves and rotate around a filament-like core. But the filaments need not be straight: They can bend, twist, and tangle. Until now, however, the filaments could not be visualized, only simulated. Using high-speed, 4D ultrasound, Jan Christoph of the Max Planck Institute for Dynamics and Self-Organization and colleagues have now observed the dynamics of mechanical filaments' 3D structures inside an *in vitro* animal heart experiencing cardiac arrhythmias. The figure shows an example of the phase of two counterrotating mechanical waves recorded in the left ventricular wall, viewed from the side (main view) and top (inset). The waves encircle a U-shaped filament that extends from the surface (red points) into the heart and back. Such mechanical filaments align closely with the electrical vortex cores seen with fluorescence imaging. Moreover, the mechanical filaments could be tracked as they drifted, twisted, and interacted; they functioned as fingerprints of electrical activity, revealing the topological organization of the fibrillation in the heart wall and offering insights into the mutual coupling between mechanical and electrical waves during cardiac arrhythmias. (J. Christoph et al., *Nature* **555**, 667, 2018.) —RJF PT