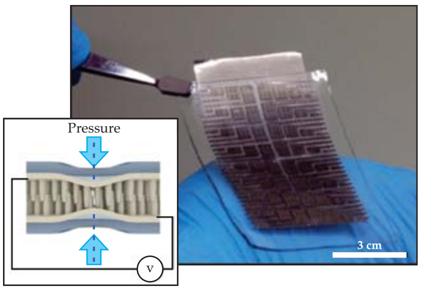
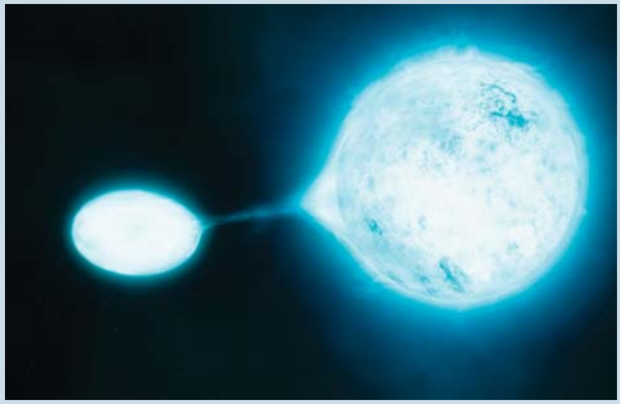
physics update

These items, with supplementary material, first appeared at http://www.physicstoday.org.

Platinum hairs add finishing touch to artificial skin. As a mechanical sensor, human skin is uniquely versatile: It can detect not just the magnitude of a contact force but the particulars of how the force is applied. Thus, we know whether we're being poked or pinched, tapped or tugged. Now, researchers led by Kahp-Yang Suh (Seoul National University, South Korea) have engineered an electronic skin that can similarly discriminate between various kinds of touch. The skin consists of two thin polymer sheets, each lined with hair-like, platinum-coated nanofibers. When the sheets are sandwiched together, as illustrated at left, the nanofibers—each about a micron long and a tenth of a micron wide—interlock to form Pt–Pt contacts that close an electronic circuit. The total contact area, and therefore the resistance, changes when the sheet is subjected to mechanical stress. Pressure, shear, and torsion each produce distinct electronic signatures, so even when all three are applied at once, the detected stress can be resolved into its component parts. In laboratory tests, the artificial skin, pictured at right, proved sensitive enough to track the movement of crawling ladybugs and detect the impact of a falling water droplet. The researchers envision the thin, flexible sensors being used as prosthetic devices or medical monitors; worn like a bandage on the wrist, the device can easily measure a human pulse. (C. Pang et al., *Nat. Mat.*, in press.) —AGS



Most very bright stars have companions. With masses at least 15 times that of the Sun, type-O stars are the heaviest and brightest of all. And because they live only a few million years, they're quite rare. Having analyzed the O-star populations of six nearby star clusters, a team led by Hugues Sana (Amsterdam University) has concluded that over 70% of O stars—far more than had been thought—have binary companions close enough to exchange matter with them. Interaction with companions, large or small, would therefore seem to dominate the evolution of the massive stars, and it should now be taken into account when interpreting observations of distant star-forming galaxies. A smaller companion might become a "vampire star" (see the artist's impression), sucking away the O star's hydrogen envelope, or it might itself be swallowed up. The team estimates the probabilities of different O-star fates by deducing the distribution of binary-pair orbital parameters from periodic Doppler shifts in spectra taken mostly with the Very Large Telescope array in Chile. For significant binary interaction and reasonable detection probability, a companion's orbital period should be less than about four years. O stars end their lives in core-collapse supernovae that seed the host galaxy with heavy elements. The team's estimate of the fraction of O stars that lose their hydrogen envelopes to vampires resolves an old puzzle; it's in good agreement with the observed frequency of core-collapse supernovae that exhibit no hydrogen lines. (H. Sana et al., *Science* **337**, 444, 2012.) —BMS

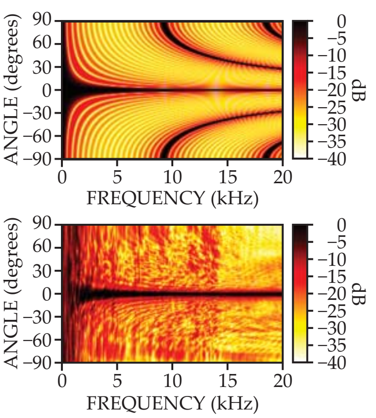


ESO/M. KORNMESSER/S. DE MINK

Toward a compact microbeam radiotherapy system. The intense, narrow x-ray beams produced by synchrotrons are ideal for zapping tumors: With diameters of just 10–100 µm, the beams deliver a dose pattern with exquisite precision. What's more, for some unknown reason, the beams' high intensity is both more effective at killing tumors and less damaging to healthy tissue than are the lower-intensity beams used in conventional radiotherapy. But synchrotrons are large, expensive, and sparsely distributed. To circumvent those disadvantages, Sha Chang and Otto Zhou of the University of North Carolina in Chapel Hill are developing a compact, convenient method for bringing what's known as microbeam radiotherapy into the clinic. Their approach entails producing x rays by slamming high-energy electrons into a tungsten anode, just as in dental cameras and other medical x-ray devices. But instead of boiling off the electrons from a metal cathode, they use the field effect to extract the electrons from a cathode made from carbon nanotubes. Thanks to the nanotubes' tiny diameters, the resulting x-ray beams, while not as powerful as those from synchrotrons, are almost as narrow. To assess whether the technology is practical, Chang and her colleague Eric Schreiber simulated a device capable of treating lab mice. The virtual device consists of a circular array of 12 or more units that direct their beams inward toward the circle's center. As they report in a new paper, the device can indeed deliver a tumor-killing dose to tightly defined volumes within a phantom mouse. The researchers are now testing their first prototype. (E. C. Schreiber, S. X. Chang, *Med. Phys.* **39**, 4669, 2012.) —CD

Optical vortex pulses. In addition to having spin angular momentum, light beams can also have orbital angular momentum (see the article by Miles Padgett, Johannes Courtial, and Les Allen in PHYSICS TODAY, May 2004, page 35). Often called vortex beams, they have a helical wavefront and a doughnut-shaped profile with vanishing intensity along the beam axis, and they are being increasingly used in applications such as rotating particles in optical tweezers. Though most investigations with optical vortex beams have focused on continuous-wave (CW) operation, pulsed vortex beams could open up several additional applications in materials processing or nonlinear frequency conversion. Now Haohai Yu (Shandong University) and colleagues have demonstrated a new approach for directly and controllably generating pulsed vortex beams. To drive their pulsed laser, the researchers use a CW commercial laser diode that also has a doughnut-shaped profile. As the pump power increases, thermal effects in the pulsed laser cavity change the vortex mode that best couples to the input beam and gets preferentially pumped. Finally, a standard technique known as passive *Q* switching allows power to build up inside the cavity until it can be released in a short pulse. The net result is a train of stable, single-mode pulses with changeable vorticity. The pulses can also pack quite a punch: With roughly 10 W of pump power, the team demonstrated pulse energies up to 63 μJ and peak powers of more than 4.5 kW. (Y. Zhao et al., *Appl. Phys. Lett.* **101**, 031113, 2012.) —RJF

Seeing the sound to locate its source. Several microphones arranged in a given pattern can be used to locate a sound source by analyzing the phase mismatches of the signal at different receivers. That long-established technique is called beamforming. The top panel of the figure shows the output from a line of 19 microphones in response to a simulated incident plane wave. The dark lane at 0° identifies the direction of the source as being broadside; that lane would shift up or down for a source in a different angular direction. The other dark lanes appearing at high frequencies are unavoidable artifacts—spatial aliasing—due to the discrete separations of a finite number of microphones. Those artifacts limit the technique to the lowest frequencies.



If infinitely many microphones formed a continuous line, the artifacts would go away and a larger frequency range could be used. Researchers from the Danish Fundamental Metrology Institute and the Technical University of Denmark recognized that sound creates variations in pressure—and thus in density—and that those variations affect the phase velocity of light. So they replaced the line of discrete microphones with a continuous laser beam, generated in a laser Doppler vibrometer (LDV) that typically samples a vibrating surface. Instead, they had the beam reflect off a rock-solid mirror and back into the LDV, thereby sampling the sound fluctuations along its path. The bottom panel shows an experimental realization of the researchers' theoretical analysis, with 0° now representing the head-on direction. With the LDV and reflector mounted on a turntable, the beamformer can be steered to find an acoustic source without any trace of spatial aliasing. The technique may prove useful where microphones cannot be deployed, such as in high-temperature environments. (A. Torras-Rosell, S. Barrera-Figueroa, F. Jacobsen, *J. Acoust. Soc. Amer.* **132**, 144, 2012.) —SGB

Earth's changing orbit shows up in tree ring data. Under the gravitational influence of Jupiter and Saturn, the eccentricity of Earth's orbit and the tilt and precession of its rotation axis slowly fluctuate. Those changes affect how much solar radiation reaches a given geographical location and are responsible for Earth's ice ages. According to a new study, they are also responsible for a more recent phenomenon: the cooling of Scandinavia from 138 BC to AD 1900 at a steady and significant rate of 0.31° per 1000 years. To reach that finding, Jan Esper of Johannes Gutenberg University Mainz in Germany and his collaborators assembled a record of tree rings from the trunks of young and long-dead Scots pines at 17 sites in northern Finland and Sweden. Thanks to the sites' stability and the availability of buried and submerged trunks, the record is unprecedented in its continuity and consistency. Orbital calculations indicate that summer insolation at northern latitudes has indeed been declining steadily for the past 2000 years, consistent with the long-term cooling that Esper and his collaborators inferred from their tree rings. However, the cooling trend is absent from other, less homogeneous tree-ring records that have been used to reconstruct northern Europe's past climate. If the Scandinavian tree rings embody the climate's true behavior, then summer temperatures during Roman times and the Medieval Warm Period were a few tenths of a degree higher than previously estimated. Yet even though summer insolation continues to fall in Scandinavia, the temperature trend manifested by the region's trees after 1900 is upward. (J. Esper et al., *Nat. Clim. Change*, in press.) —CD

Microfluidic chip sorts the living from the dead. When a cell meets its demise, so too does its fine-tuned system for regulating nutrient uptake and waste excretion. As a result, cell death is typically marked by a sharp increase in electrical conductivity, as various ions become free to pass through newly opened pores in the cell membrane. That telltale change affords a convenient way to sort live cells from dead ones: In what's known as dielectrophoresis, electric-field gradients induce cells to migrate with a conductivity-dependent velocity. Exploiting the effect typically calls for fashioning tiny electrodes inside a microfluidic channel, but a group led by Xiangchun Xuan of Clemson University, South Carolina, has now devised a simpler alternative. The key was recognizing that a severe flow constriction is often sufficient, by itself, to distort an otherwise uniform electric field and create the strong gradients needed for dielectrophoresis. The essential component of the Clemson team's device is pictured here. Yeast cells generally flow from left to right, from a reservoir into a narrow microchannel, but near the constriction, dielectrophoretic forces oppose the bulk flow. Since those forces act more strongly on dead yeast than live yeast, they can be tailored to trap dead cells in the reservoir while allowing live ones—fluorescent green in the image—to enter the channel. The researchers anticipate that their design can be integrated into lab-on-a-chip devices to aid in biomedical diagnostics and drug screening. (S. Patel et al., *Biomicrofluidics* **6**, 034102, 2012.) —AGS ■