Submicron room-temperature imaging

Stephen G. Benka

Citation: Physics Today 56(6), 9 (2003); doi: 10.1063/1.4797060
View online: http://dx.doi.org/10.1063/1.4797060
View Table of Contents: http://scitation.aip.org/content/aip/magazine/physicstoday/56/6?ver=pdfcov
Published by the AIP Publishing

Charge symmetry breaking (CSB) has been observed in two experiments, reported in April at the American Physical Society meeting in Philadelphia. In the 1930s, Werner Heisenberg proposed that the neutron and proton are slightly different manifestations of the same particle, the "nucleon." Modern nuclear physics endorses this view: Many nuclear reactions proceed exactly the same if a proton replaces a neutron, or vice versa. However, the similarity of protons and neutrons breaks down in some cases, leading to CSB. Edward Stephenson of Indiana University announced the first unambiguous identification of a process that is forbidden if charge symmetry is exact: the fusion of two deuterium nuclei to form a helium nucleus and a neutral pion. The experiment was conducted over a two-month period at the Indiana University Cyclotron Facility. Allena Opper of Ohio University discussed the other result: the fusion of a proton and neutron to form a deuteron and a neutral pion. The experiment—a collaboration at the TRIUMF cyclotron in Canada—revealed a hallmark of CSB: A small excess of deuterons emerged in a preferred direction. CSB has been observed many times before, but the new results promise a wealth of information on such things as the slightly different electromagnetic fields inside each nucleon and why the neutron and proton have slightly different masses. The results can also potentially yield more precise values of the mass difference between the up and down quarks that make up protons and neutrons. —BPS

First scientific results from LIGO (the Laser Interferometer Gravitational-Wave Observatory). Essentially a giant strain gauge to measure the local distortion in spacetime of a passing gravitational wave, LIGO has detectors in Hanford, Washington, and Livingston, Louisiana. (For more on LIGO's operation, see PHYSICS TODAY, October 1999, page 44.) The ripples in spacetime radiated, for example, by the collapsing inspiral of two neutron stars are predicted to produce a strain in LIGO of perhaps one part in 10^{20}, which would change the distance between mirrors some 4 km apart by about 10^{-18} meters, a displacement 1000 times smaller than a proton. At the April APS meeting, the LIGO team reported its first official results from the initial science run, conducted over 17 days in the late summer of 2002. Gary Sanders (Caltech) and Erik Katsavounidis (MIT) reported that, as expected, no gravitational-wave events were seen, but new upper limits were set on three of the four prime source categories. For coalescing binaries, no more than 164 events per year are expected from the Milky Way or an equivalent galaxy. The limit for both known and unknown burst sources, at a strain of 10^{-17}, is 1.4 events per day. Using one pulsar as a test case, LIGO has demonstrated sensitivity to pulsar sources at a strain amplitude of 10^{-22}, within a factor of 100 of that expected from the Crab pulsar. Finally, LIGO's limit on stochastic waves that could have arisen in the early universe—expressed as their contribution to the energy density needed to close the universe—has Ω_{GW} less than 72.4, a bit higher than the current best limit of 60. All of these limits are expected to improve dramatically after data from the recently concluded second science run, with its tenfold increase in sensitivity, are analyzed. —PFS

Single-molecule, single-base-resolution DNA sequencing has been demonstrated. Decoding single-molecule DNA strands is intrinsically difficult because of the high linear data-storage density: The base molecules are only about 3.4 Å apart. Now, a group at Caltech has used a DNA polymerase enzyme to add complementary base units, one at a time, to a single strand of DNA. The base molecules being added were fluorescently labeled beforehand, so the newest member of the DNA sequence at each stage could be observed as it fluoresced. The scientists minimized background noise through careful use of two laser pulses: one to produce pinpoint fluorescence and the other to null or "bleach" the fluorescence to prepare for the next base incorporation. Thus far, sequences of up to six bases have been read. Stephen Quake believes that, within about two years, his group's process should be a factor of ten faster than standard gel-electrophoresis techniques currently used to sequence DNA molecules, and several orders of magnitude cheaper. (I. Braslavsky et al., *Proc. Natl. Acad. Sci. USA* **100**, 3960, 2003.) —PFS

Submicron room-temperature imaging of buried electrical current has been developed. Physicists Gang Xiao and Ben Schrag at Brown University used a magnetoresistance sensor just tens of nanometers across as the basis for their scanning magnetic microscope. By placing the sensor in physical contact with the surface of a current-carrying sample and then rastering continuously, they were able to image the surface magnetic field structure. They then inverted that structure to deduce the current distribution. Shown here is the time development (top to bottom) of electromigration voids (in blue) and hotspots (in red) near the anode of a 3-μm-wide aluminum conductor covered by a 0.1-μm-thick layer of silicon dioxide. (B. D. Schrag, G. Xiao, *Appl. Phys. Lett.* **82**, 3272, 2003.) —SGB