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Physics News in 2006 pages 5-10

APS Commemorates Birth of the Transistor


Photo: John Skalko

On December 14, APS President (now past-President) John Hopfield visited Bell Labs in New Jersey, where he had been a postdoc in the late 1950's. His purpose was to present a plaque, on behalf of the APS Historic Sites Initiative, honoring the invention of the transistor by (in alphabetical order) John Bardeen, Walter Brattain, and William Shockley. "I am immensely pleased to be here as the representative of the American Physical Society in the proceedings today," Hopfield said at the presentation ceremony. "Many years ago, I was a kid interested in electronics, and built radios based on a single vacuum tube, normally a triode. Elegant little machines, with this single triode serving simultaneously three functions, as the RF amplifier, the detector or demodulator, and the audio amplifier. A vacuum tube triode would cost about $1.00. How preposterous it would have seemed that someone would tell me that I would have, in my laptop computer, 10 billion dollars worth of vacuum tube-equivalents, inflation non-adjusted. Multiply both numbers by 10 to account for inflation over the years, and that does not alter the amazement." Hopfield concluded his remarks with "I am personally so happy to be part of an occasion commemorating the past, honoring the present, and looking to the future of Bell Labs. And honoring and commemorating three distinguished members of the American Physical Society."

In the photo, Hopfield (right) looks on while President of Bell Labs, Jeong Kim, signs the official APS register of historic sites.

APS Membership Sets A New Record in 2007

The official APS membership count set a new all-time record again in 2007. The count, taken on January 8, 2007, blasted through the 46,000 barrier, reaching a total of 46,293 for an increase of 774 over 2006. Analysts said that the declining price of oil, coupled with a modest inflation rate, had absolutely nothing to do with it.

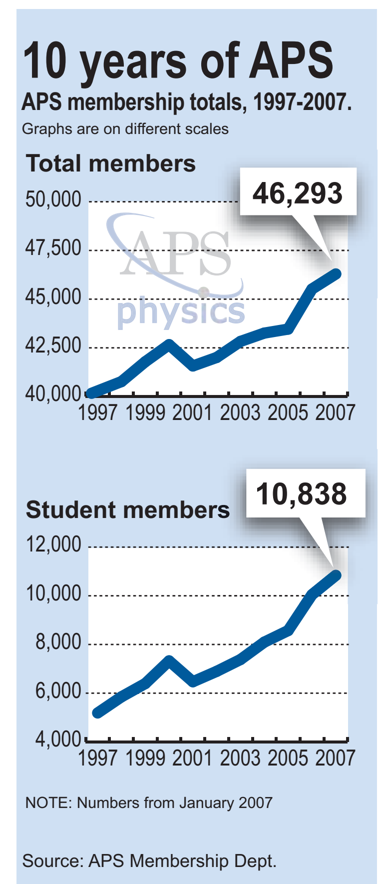
Rather, according to Director of Membership Trish Lettieri, continued growth in the student member category was the leading factor. "Although every member category had fluctuations throughout the year, the overall growth correlates to the increase in student members," she said. "Students are up 793 from last year, for a total of 10,838 student members."

Students in North America receive one year free as a trial membership, and their dues after that are currently $28 per year. Lettieri says it's encouraging that the student category is so strong, because it augurs well for the future of the Society.

One area in which membership totals play an important role is with respect to lobbying activities. As a registered lobbyist in Washington, APS seeks to promote the health of the profession by arguing for science funding, and to bring science into the policy arena by advocating on issues mandated by Council. The impact that APS can have is related to the size of the Society. By law, APS lobbying is limited by the amount of membership dues. In addition, the more members who engage in grass-roots activities such as letter-writing and personal visits to Congress, the more effective APS can be.

APS membership also has a significant international component. There are over 9500 members from outside the US, representing 21% of the total. The countries with the largest representation are Japan (1805) and Canada (1198).

While the student members continue to increase, at the other end of the demographic spectrum, retired members also show modest growth. Their number went up from 5534 in 2006 to 5598 in 2007.



APS News staff

Serious Consequences Loom If FY07 Budget Is Frozen

Instead of the expected increases, federal funding for physical sciences for Fiscal Year 2007 may be frozen at FY06 levels because Congress failed to pass a budget for FY07. This will have serious consequences for the science and education programs in the United States, including potential cutbacks in operations at several major national labs, delays in some scheduled projects, and reductions in the number of new research grants.

Expected budget increases for the physical sciences were put on hold last fall when Congress adjourned having passed only two appropriations bills, for homeland security and defense. A continuing resolution kept funding at FY06 levels through mid-February 2007.

When the new Congress took office in early January, congressional leaders announced their intention not to address FY07 funding bills, and instead pass another continuing resolution holding funding at FY06 levels throughout all of FY07, which ends in October. This would allow the new Congress to turn its attention to FY08 funding, with the President's FY08 funding request scheduled to be released in early February.

After decades of relatively flat funding, FY07 was expected to be a good year for physical science funding. President Bush's proposed American Competitiveness Initiative, which had bipartisan support, would have doubled funding for science over ten years. For FY07, the administration had requested a 14% increase for the Department of Energy Office of Science and a 7.8% boost for the National Science Foundation.

Instead, without action by Congress, funding will be held at FY06 levels, which was a poor year for physical science funding. The $3.5-billion FY 2006 appropriation for the DOE Office of Science represented a real decline of almost 7 %. Some national labs had been delaying cuts in operations in 2006 based on the expectation that funding would increase in 2007. In addition, mandated raises and other increases have automatically taken effect, meaning that just to maintain the same level of effort in 2007 requires more funding.

In early January APS Executive Officer Judy Franz sent an alert to all APS members, asking them to write to their representatives and urge Congress to enact increases for the budgets of the NSF, DOE Office of Science, and NIST Scientific and Technical Research and Services (STRS) account in the upcoming Continuing Resolution for FY07.

It is possible that Congress could make adjustments for select agencies when it passes the yearlong resolution. Congress could allow the DOE to reprogram their allocations to fund the DOE Office of Science at the proposed FY07 levels by shifting funds that had been allocated to the cleanup of several large nuclear waste sites since the cleanup is now complete.

One lab that would be particularly hard hit by the budget freeze would be the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory. The FY06 budget left RHIC with a shortfall of about $20 million, and RHIC was only able to keep running thanks to private dona-

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Thursday Night Football with Tim Gay

March Meeting attendees are invited to join Denver-area residents on Thursday, March 8 for a night of football physics with Tim Gay, Professor of Physics at the University of Nebraska–Lincoln. Gay is author of *The Physics of Football: Discover the Science of Bone-Crunching Hits, Soaring Field Goals, and Awe-Inspiring Passes*. The talk will begin at 7:00 p.m. and be followed by a book signing.

PhysicsQuest Kits Are Back by Popular Demand

Buoyed by the enthusiastic response of teachers and students, the APS has extended funding for its year-old PhysicsQuest program for several additional years. PhysicsQuest is a story-based learning adventure that consists of a free activity kit sent to registered 6th to 9th grade physical science teachers.

"PhysicsQuest provides 6th to 9th graders with a positive and fun experience with physics," says Jessica Clark, Head of Public Outreach for APS. By continuing the program, the APS hopes to not only increase the number of participating classrooms, but also to "foster a locally active community of physicists–one that impacts the science education in their local areas."

KGJ/APS staff

The kits are provided to teachers free of charge, one per class, although educators may register more than one class. Students work together to complete four experiments to gather "clues" to the "mystery." They then submit their results to APS for a chance to win prizes. The kit includes teacher guides, student guides, and all of the materials students will need to complete the experiments. Last fall, the Society set out a total of 8650 kits to more than 2100 teachers.

The PhysicsQuest program was established in 2005 as part of the World Year of Physics celebrating Einstein's "miracle year," in which he published three papers that helped revolutionize physics. In 2005, students were asked to solve the mystery of Einstein's "hidden treasure," using clues provided in the activity kits.

Teachers responded with enthusiasm, praising the program for its innovative approach to encouraging middle school students to participate in hands-on physics. "The best part was to see the interest that was sparked in students who are normally disinterested," one teacher wrote. Said another, "I believe that many of my students have decided to study physics at the high school level, when before they believed that they were not smart enough to do so."

That is one of the primary goals of the program, according to Kendra Rand, Public Outreach Specialist for APS: to provide students with a positive experience with physics, in hopes that they will be more open to participating in future physics experiences. "We realize that a 50-minute class activity won't effectively teach students about circuits," says Rand. "But if it can draw them in enough so they consider taking physics when choosing their high school classes, or to consider a more challenging science project, we consider that a success."

PHYSICS QUEST cont. on page 4

Members in the Media

"Our opinion is that fractal analysis doesn't give you the right to have an opinion."

***Harsh Mathur**, Case Western Reserve University, claiming misuse of fractal analysis to judge the authenticity of a Jackson Pollock painting, Cleveland Plain Dealer, December 25, 2006*

"I welcome open, intelligent discussions on fractal analysis. My scientific reputation does not hinge on this controversy, but rests on the more than 200 publications I have authored in the past 20 years."

***Richard Taylor**, University of Oregon, on other people's criticism of his work on fractal analysis of Pollock paintings, Cleveland Plain Dealer, December 25, 2006*

"We feel that we've really only scratched the surface and the comet has already given us some surprises and mysteries. So it's going to keep us busy for a long time."

***Andrew Westphal**, University of California, Berkeley, on analyzing dust grains collected from a comet with NASA's Stardust mission. Contra Costa Times, December 15, 2006*

"I couldn't figure out why. It drove me nuts. But when I began to study it, it turned out to be all basic physics."

***Diandra Leslie-Pelecky**, University of Nebraska-Lincoln, on seeing a race car crash into a wall, which inspired her to write a book on the physics of NASCAR, Christian Science Monitor, January 2, 2007*

"Supersymmetry is a vital part of string theory, so if the LHC doesn't find it, that would argue strongly against string theory. If it is observed, you can say that string theory has not been disproved, but not that it has been validated."

***Lawrence Krauss**, Case Western Reserve University, Wall Street Journal, January 5, 2007*

"I thought he was trying to do what he could to keep a declining operation functioning as well as he could."

***Gerald E. Marsh**, on Linton Brooks' dismissal as head of the National Nuclear Security Administration, The New York Times, January 5, 2007*

"I like to think of visible matter as the olive in the martini of dark matter."

***Sean Carroll**, Caltech, Los Angeles Times, January 8, 2007*

"It was as if his internal organs received a severe sunburn and peeled."

***Peter D. Zimmerman**, King's College, London, on the poisoning of Russian spy Alexander Litvinenko with polonium-210, Los Angeles Times, January 1, 2007*

"Nobody has built an instrument this sensitive. It is a probe into the unknown."

***Ramanath Cowsik**, Washington University, on an experiment to measure gravity more precisely, St. Louis Post-Dispatch, January 8, 2007*

"It's one thing to have all the components working and another to have them all working together. To me, that's the key technical issue that has yet to be resolved."

***Raymond Jeanloz**, University of California, Berkeley, on untested replacement nuclear warheads, The New York Times, January 7, 2007*

Engineering Academy Seeks Grand Challenges

In September, the National Academy of Engineering will announce 20 Grand Challenges in Engineering for the 21st century. The challenges will be identified by a distinguished panel, chaired by former Defense Secretary William Perry. Says NAE President William Wulf, "we hope that the outcomes of this project will provide a guide toward the future for engineers, a tangible motivation for young people who want to make a difference, and a better public understanding about how engineering shapes our world."

The Academy and the committee are asking for community input, which can be given at the Grand Challenge web site, www.engineeringchallenges.org. According to Wulf, those nominating grand challenges should consider particularly the areas of their expertise, and include pertinent back-up materials.

Among the other committee members are former NIH Director Bernadine Healy, "Applied Minds" Chairman and former Disney Imagineer Danny Hillis, Google co-founder Larry Page, APS Fellow and Princeton professor Robert Socolow, and human genome sequencer J. Craig Venter.

This Month in Physics History

February 3, 1851: Léon Foucault demonstrates that Earth rotates

By the mid 19th century, most educated people knew that Earth spins on its axis, completing a rotation once a day, but there was no obvious visual demonstration of the Earth's rotation, only astronomical evidence.

As early as Galileo's time, scientists had tried to demonstrate Earth's rotation by dropping objects and measuring how far eastward they landed, but these efforts were too crude and inaccurate to be conclusive.

Not until Léon Foucault's famous pendulum demonstration in 1851 was there clear dynamical proof of Earth's rotation.

Jean Bernard Léon Foucault was born in Paris in September 1819, the son of a publisher. In his school days, he was a rather timid boy and never had much success academically. Much of his education was obtained at home. His mother wanted him to become a doctor, so he enrolled in medical school, but he quickly found he couldn't stand the sight of blood and dropped out.

Hulton Getty/Stone

Foucault lacked formal scientific training, but he had great dexterity, a talent for building mechanical gadgets, and a great intuitive understanding of nature.

After leaving medical school, Foucault worked as a lab assistant. He then took an interest in the recently invented Daguerre photographic process and used it to produce the first photograph of the sun. With his collaborator Armand Fizeau, he devised a way to measure the speed of light using rotating mirrors, and in 1850, he showed that light travels more slowly in water than in air.

One night in early January 1851, at about 2 a.m. according to his journals, Foucault had an insight. He realized that if he could devise a way to hang a pendulum from the ceiling in such a way that the pendulum was free to swing in any direction, he would be able to see the effect of Earth's rotation. It would appear that the pendulum's path was slowly shifting, while in fact the pendulum's plane of oscillation would stay fixed while Earth turned beneath it.

He realized the pendulum had to be designed very carefully. The bob must be perfectly symmetrical. When starting the pendulum swinging, it had to be released gently, as the slightest push would ruin the demonstration. But if done properly, it would be the first clear and dramatic demonstration of the Earth's rotation.

After successfully completing the experiment in his basement, he was ready to try it on a larger scale. On February 2, 1851, Foucault sent a notice to scientists in Paris, saying "You are invited to see the Earth turn."

The next day, in the Meridian Room of the Paris Observatory, the assembled scientists did indeed witness the Earth turn. The first pendulum demonstration was a success.

Foucault had also derived a simple equation, known as his sine law, which gives the time it would take for a pendulum at any given latitude to complete a rotation. At the equator, the pendulum's plane of oscillation would never move, while at the North Pole the plane of the pendulum would complete a 360 degree rotation in 24 hours. In Paris, the pendulum would turn 270 degrees in a day.

Although this first demonstration was a success, the elitist scientific establishment, which had never accepted Foucault because of his lack of scientific training, was slow to appreciate his results. Possibly they were annoyed that they had not made the discovery themselves. Some tried to claim priority, but Foucault was indeed the first to propose the simple sine law. In fact, some scientists at the time had predicted that the effect Foucault had so clearly demonstrated would not occur at all, or would be too small to observe.

Foucault repeated the demonstration for the public in March in the Pantheon, an ideal building for such an impressive demonstration because of its high dome. Foucault had the Pantheon's elegant marble floor covered with a wood platform, on which he spread a thin layer of sand, so that the pendulum pointer traced out its path in the sand, making the slow rotation clear. The pendulum itself was a 28 kg brass bob, 38 cm in diameter, hanging on a 67 meter long wire.

The public was enthralled by the striking demonstration. Ordinary Parisians flocked to see the exhibit. Foucault became a celebrity, and soon many more such pendulums appeared in cities around the world.

Foucault continued his scientific work. Within a year of first demonstrating his pendulum, Foucault went on to invent the gyroscope as another way to show Earth's rotation. For another exhibition of the pendulum in Paris in 1855, Foucault invented a device that would give the bob an electromagnetic kick to keep it from slowing down and eventually coming to a stop.

Napoleon III, who was himself an amateur scientist and supportive of Foucault, arranged for him to hold the position of Physicist Attached to the Imperial Observatory, where he made significant improvements to the telescopes. Still the French Academy of Science was reluctant to elect him to membership. Eventually, after petitioning several times, Foucault was finally elected in 1865. He died in Paris on February 11, 1868, at age 49.

The public continues to be fascinated with Foucault pendulums, which can be found in science museums and other public spaces around the world.

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tion. This year, with funding frozen and no private donation, RHIC will be forced to shut down for the year, said Brookhaven director Sam Aronson. "The long and short of it is that we would not be able to operate the machine this year."

This is a particularly unfortunate time for a budget freeze, because RHIC scientists were gearing up to upgrade the detectors and were looking forward to a high statistics run with heavy gold ions. RHIC was hoping to get some more good results before the more powerful LHC heavy ion effort goes online.

In addition to delaying the science for a year, said Aronson, "That doesn't send a good message to the community."

Brookhaven was also planning a new light source, the NSLS, which was scheduled for $45 million for project-related R&D in FY07. That project would be delayed as well.

If there is no funding above the FY06 level, staff reductions at Brookhaven will be necessary, said Aronson. Electric power costs and manpower costs are significant. "When we have a bad budget year, we can't help but look at potential layoffs," said Aronson. As many as 100-200 staff members could be cut, he said.

Continuing funding at the FY06 level would also force Fermilab to shut down for a month. In a report to DOE Undersecretary Ray Orbach in December, Fermilab Director Pier Oddone pointed out that Fermilab's major facility, the Tevatron, had only a short time to run before being superseded by the LHC at CERN. "The Tevatron program is constrained by the start-up of LHC," Oddone's report says, "so it must be run effectively during the limited time before shutdown in FY2009. It does not make sense to shut down the Tevatron for the remainder of the year in a manner similar to BNL's stopping operation of RHIC while maintaining the work force to run the facility at some later year."

Fusion science would also suffer cutbacks. Last fall the US signed an agreement to contribute to ITER (see International News on this page), but under a continuing resolution, the US contribution would be reduced to half the planned level. US R&D efforts for ITER would be severely limited, delaying the progress of R&D for the US hardware contribution by a year.

"The impact of not doing the ITER work would really be failing to meet an international commitment," said Rob Goldston, director of the Princeton Plasma Physics Laboratory.

As an alternative, if the DOE is allowed some flexibility, the US could maintain a $45 million minimal funding level for ITER by cutting domestic fusion research programs, including the NSTX at PPPL. Either way, said Goldston, "It would be really devastating."

According to an analysis by the APS Washington office, at NSF the funding freeze would result in a 10% reduction in the number of new research grants and $439 million in missed opportunities for scientific discoveries, including programs designed to implement the American Competitiveness Initiative.

The APS Washington office also predicts that if Congress fails to increase the DOE Office of Science budget, as many as 2000 scientific and technical staff members at the national laboratories will lose their jobs. In addition to the cuts at RHIC and Fermilab, one of the four synchrotron x-ray sources that are crucial to biomedicine and materials science will be threatened with closure, and the opening of the new $1.4-billion Spallation Neutron Source at Oak Ridge National Laboratory will be delayed by a year.

Other DOE-SC user facilities will suffer major cutbacks in operating time, and construction of new facilities, including the Linac Coherent Light Source at Stanford, will be put on hold or delayed. University research support will also decline by about 10 percent.

APS members can find out more and write to Congress by going to http://www.aps.org/policy/issues/research-funding/budgets.cfm

INTERNATIONAL News
...from the APS Office of International Affairs

The ITER Agreement–Four Decades for Me and Counting

By Michael Roberts

The agreement that was recently signed by seven major scientific powers to construct ITER (formerly known as the International Thermonuclear Engineering Reactor) represents a milestone in international scientific collaboration. More than an agreement to build a multibillion dollar scientific facility, this accomplishment represents a joint statement on how these seven Parties, representing half the world's population, can work together toward a common, major, and long-term scientific goal.

ITER is a joint international research and development project that aims to demonstrate the scientific and technical feasibility of fusion power. The partners in the project–the ITER Parties–are the European Union (represented by EURATOM), Japan, the People´s Republic of China, India, the Republic of Korea, the Russian Federation and the USA. ITER will be constructed in Europe, at Cadarache in the South of France. For more information, please see www.ITER.org

It has been a long time coming. In 1968, I was one of 60 US fusion scientists who joined hundreds of researchers from other nations at the first International Atomic Energy Agency (IAEA) fusion energy conference in the USSR in Academgorodok, near Novosibirsk. The tokamak magnetic confinement experiments–the basis for ITER–were first broadly discussed in an international forum there. In addition to the technical discussions, and despite the Cold War tensions, we got to know each other through personal interactions, e.g., playing frisbee, exchanging token gifts. I believe these interactions led to successful bilateral fusion activities arising from the 1973 Nixon-Brezhnev Atomic Energy agreement. During the 1970/80s, frequent broadly based informal interactions between U.S. fusion scientists and their European Community counterparts built a straightforward working trust between many of us on both sides. In November, 1979, now representing the US Department of Energy, I sat down for the first time in a bilateral program negotiation with my Japanese counterparts, trying to implement what President Carter and Prime Minister Fukuda had recently agreed should happen. In front of us was a first year plan of 29 research exchange visits, and both programs' governmental and technical leaders expected us staffers to report back soon. We kept sending notes requesting more time and after EIGHT HOURS of argument brought in our recommendations for the first annual plan of activities. Two decades later, with the help of smooth running prior staff work, we would be able to approve plans of hundreds of complex interactions in literally one minute at formal meetings, leaving time for substantive discussion of program issues. Multilateral engagement in fusion intensified in 1982, when French President Mitterand led the Versailles Summit to adopt an initiative on Technology, Growth and Employment including a Fusion Working Group. I had the good fortune to participate in this activity that developed a Western world fusion plan in 1983-4. This in turn led to discussions with the USSR toward a world program plan for major facilities. By the time of the November, 1985 US-USSR Geneva Summit, Academician Evgeniy Velikhov had conceived of what has become ITER, an idea that was adopted by President Reagan and General Secretary Gorbachev and then presented to the European Community (EC) and Japan. When ITER was born, international fusion was based principally on collaboration among the EC, Japan, US and USSR. In the next decade, US fusion bilaterals developed with China and Korea led to working relationships with fusion programs in these countries. A bilateral arrangement with India, the last major fusion program state not in the international collaboration milieu, is just now being developed as a result of the meeting between President Bush and Prime Minister Singh in mid-2005. Nonetheless, there is a long history of personal US-India fusion relations; as the head of the Indian fusion program, I and other international colleagues worked together on the IAEA's International Fusion Research Council and built personal friendships that facilitated India's involvement with ITER. With bilaterals with India now being developed (starting with the EU, US, and Korea), all the world's major fusion programs are now interacting through ITER and, in part, through bilaterals as well.

Strengthening these many bilateral programs was the multilateral International Energy Agency (IEA) fusion activity. In each of the bilaterals and in the IEA and IAEA fora, I was privileged to be the US Executive Secretary or US working level representative, providing a quarter-century of continuity for US international fusion collaboration. In these roles, I learned to listen, persuade, compromise and generally find ways to implement agreed policies. During these years, the underlying bilaterals and multilaterals have matured, and the scientific and administrative work on the ITER project has advanced. These activities enabled the building of trust among us representatives of the involved governmental authorities (the Parties to the ITER Agreement) and built a strong base for serious ITER negotiations conducted at the political and diplomatic level since 2001. While the early years of ITER (~1985-2000) could be said to have focused on the "What of ITER" (i.e., the scientific objectives, basis, approach and design), the formal governmental negotiations since 2001 have turned to the "How of ITER" (i.e., resources, governance, legal matters)–a shift of emphasis that has implications that go well beyond fusion research.

Those most directly interested in the "What of ITER" are fusion scientists, since the issues addressed are largely fusion technical ones. I believe the broader science community also has an interest both in ITER science and in the funding competition ITER represents. The "How of ITER," on the other hand, directly affects government elements outside of the fusion pro-

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Physicist Finds His Fortune In the Cards

Not many people would drop $5000 on a celebratory dinner for 25 friends at the Voodoo Lounge in Las Vegas, but that's just what particle physicist Michael Binger did last August. Binger could well afford the tab: he'd just placed third in the 2006 World Series of Poker, walking away from the tables with a cool $4.1 million. Not bad for a few weeks' work.

The World Series of Poker is a world-class event, and the No-Limit Texas Hold-Em Championship is the undisputed king of the competition, with more than 8700 people coughing up the requisite $10,000 buy-in in order to do battle over the course of several weeks. Eventually it comes down to nine players at the final table. Binger came into the finals ranked 8th, with just over $3 million in chips. Somehow he parleyed that into his impressive third-place finish against some of the best professional poker players in the world, including Jamie Gold, who won top honors and $12 million.

Michael Binger

In reality, Binger's "overnight success" was the culmination of years of practice–almost as many years as the 29-year-old spent earning his PhD. A love of physics came first. Binger was a hard-core *Star Trek* fan as a child, and avidly devoured popular science books in high school. He credits his high school physics teacher with encouraging his fledgling interest in the subject, and by graduation, "it was kind of a given" that he'd make physics his chosen career.

As for poker, Binger didn't get serious about the game until he began his graduate studies in physics at Stanford Linear Accelerator Center (SLAC) under Stanley Brodsky. Binger's research focused on quantum chromodynamics, supersymmetry, and the Higgs boson.

Binger started playing small-stakes games at local poker rooms in the Bay Area, then moved up to local $200 tournaments. Eventually he amassed a sufficient bankroll to compete in higher-stakes games, although for the 2003 WSOP, he stuck with the $1500 event. He played in the main event for the first time in 2005 and admits he performed horribly.

Binger's passion for poker detracted a bit from his graduate studies: he did three years of graduate work, took a year off to play poker, then finished up his last three years. He admits that he might have finished sooner, and had a higher rate of publication, if he'd focused more on his research. But there was no quenching the poker fire. Two months after successfully defending his dissertation, he was back at the WSOP main event, and this time the gamble paid off.

There is unquestionably an element of statistics and probability involved in Texas Hold-'Em, so Binger's physics training came in handy, particularly when he was just starting out: "It was helpful to know the odds of getting dealt certain hands." But he cautions against putting too much stock in the numbers, since poker is only partially about the math.

"It's not solvable by a computer, and there's not an exactly perfect model," he told *SEED* magazine shortly after his WSOP success. "It's based on an infinite number of variables. It's not just the odds of having the best hand, drawing the best hand, the size of the pot, or other numerical factors."

Another key variable is Lady Luck. Every serious poker player has his or her share of "bad beat" stories. That's what happens when you place a large bet holding the best starting hand, and yet still end up losing on the draw. The worst disappointment is getting "sucked out on the river": when you're ahead until the very last card is drawn, almost assured of victory, but your opponent beats the odds to make that gut-shot straight, beating out your three of a kind.

That's exactly what happened to Binger during the 2006 WSOP competition. He had a day off before heading into the final round, and decided to play a few no-limit ring games in the host casino. He went all-in with a huge advantage over his opponent, and lost on the very last card. The pot size: $18,000. They agreed to run the cards again to see what would happen, and Binger's opponent once again made the

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Viewpoint...

The Virtues of Virtual Experiments

From across the pond comes the sad news that the University of Reading is phasing out its physics department, due to "budgetary constraints." Despite protests from the British physics community, led by the Institute of Physics (the rough UK equivalent of the APS), the university's ruling council voted decisively last fall to close the department by 2010, after the currently enrolled students have had a chance to graduate.

Philip Diamond, assistant director for Higher Education and Science at the IOP, noted that "the Higher Education Funding Council for England has now announced an additional £75m to support very high-cost subjects, including physics, from 2007-08 over three years. It is sad that this funding was not enough to save Reading's physics department but the institute hopes that it will prevent more closures in the future."

Diamond's statement acknowledges the fact that teaching physics is typically a more expensive enterprise than teaching, say, English literature. In major research universities, the extra expense is due in part to the laboratory space and equipment necessary for faculty members to do their research, but in smaller institutions, the big extra item is the space, equipment and staff time for all the teaching laboratories. Many smaller American colleges and universities simply do not offer physics majors, even though they do have majors in chemistry and biology. Physics is squeezed between the high cost of teaching and the typically lower enrollments of majors compared to its sister sciences. In 2004, about 25% of all bachelors' degrees were awarded to students in colleges or universities that did not have a physics major program.

A ray of hope in this perilous situation may come from a paper published in the recently established online journal *Physical Review Special Topics: Physics Education Research.* The abstract of the paper, by N. D. Finkelstein et al. (*Phys. Rev. ST Phys. Educ. Res.* 1, 010103 (2005)), is worth quoting in full:

This paper examines the effects of substituting a computer simulation for real laboratory equipment in the second semester of a large-scale introductory physics course. The direct current circuit laboratory was modified to compare the effects of using computer simulations with the effects of using real light bulbs, meters, and wires. Two groups of students, those who used real equipment and those who used a computer simulation that explicitly modeled electron flow, were compared in terms of their mastery of physics concepts and skills with real equipment. Students who used the simulated equipment outperformed their counterparts both on a conceptual survey of the domain and in the coordinated tasks of assembling a real circuit and describing how it worked.

In addition to being better pedagogically, the simulated laboratory is, of course, also less expensive to operate. Almost all undergraduates these days have their own computers. Although some computers should be made available in the physics building for their use, most of the students could log in and do the simulated experiments from their dorm rooms, libraries or study halls. There will be no need for staff to make sure the equipment is functioning, that proper safety procedures are being followed, and that all the other time-consuming but non-educational aspects of running an instructional laboratory are taken care of. And the considerable space set aside for laboratory work in introductory courses can be reduced to practically nothing.

Computer simulations as instructional devices have a significant history of success, even in areas where learning the material is of critical importance. Perhaps the best example is the use of flight simulators to teach pilots how to fly particular aircraft. First the pilot masters the basics using the flight simulator (undergraduate work) and only then does he or she get to practice on the real thing (graduate work). It's hard to imagine that significant damage would be done to the training of future generations of physics majors if most of their undergraduate laboratories were replaced by well-designed simulations on the computer.

One should also recognize that computer simulation is an important mode of research in its own right. Very often theories are tested more rapidly and effectively using simulations instead of actual experiment. And experiments depend on computer simulations for both design and data analysis. Event simulators are crucial in planning particle accelerators, and in comparing what is observed with what is predicted. Familiarity with the techniques and capabilities of computer simulation will add to the educational experience, not diminish it. And since simulations also find wide application in the commercial world, physics majors who pursue career options other than graduate school will benefit from using them in their undergraduate courses.

Undergraduate laboratories, in their current incarnation, serve a variety of purposes. They teach physics (although, apparently, less well than analogous simulations); they hammer home the message that physics is, at bottom, an experimental science; they keep students out of mischief on long afternoons; they provide a fund of anecdotes, typically more amusing to retell than to experience–the time I nearly got electrocuted; the time my cell phone fell in the liquid nitrogen; the time I dropped the (fill in your favorite expensive piece of equipment) on the floor. It is unlikely that the good old-fashioned undergraduate laboratory will ever completely disappear. But at the very least, if a college or university is facing the loss of its physics department, the replacement of real experiments by virtual ones is a very minimal price to pay for keeping the enterprise afloat.

–Alan Chodos

PHYSICS QUEST continued from page 1

This year, the story line celebrates Ben Franklin's 300th birthday year, with experiments built around Franklin's work with lenses, electrostatics, and heat transfer, all while trying to decode a secret message from 1778 by completing a "magic square": a square grid of empty boxes, in this case, 3 rows and 3 columns, which are then filled in with numbers according to a predetermined pattern. The young Ben Franklin loved to arrange numbers into patterns with special properties using such magic squares.

Even a critical misprint (since corrected) in the kit turned out to be educational. Frank Egan homeschools his three children–ages 10, 8 and 6–and ordered a PhysicsQuest kit after hearing about it from fellow homeschoolers. All three kids enjoyed the activities so much that they worked on it all through the first weekend, eager to solve the "mystery." But when they decoded the message, it didn't make any sense: "American delicacies I now miss especially."

Then 10-year-old Frank had an epiphany, realizing that with the numbers 2 and 5 in the correct position in the magic square, there was only one other possible solution. When he tried it, it gave up the right secret message (which cannot be printed here because it's, well, secret.).

Chalk up a few bonus points for the homeschooled kids: they were the first to find the error. And Egan says they're eager to participate in next year's PhysicsQuest project as well. "All three children loved doing the experiments and solving the mystery," he said. "It was a great learning experience for them, even more so because of the extra challenge provided by the error."

Next year's PhysicsQuest activity kit will focus on temperature. It is being designed in conjunction with a PBS documentary currently in production, *Absolute Zero and the Conquest of Cold*.

ON THE WEB: http://www.physicscentral.com/physicsquest

http://www.absolutezerocampaign.org

zero gravity

The Lighter Side of Science

The Uncertainty of Cat Molecules

Physicists keep uncovering evidence that unpredictability rules the universe. Molecules and atoms are not solid bits circling one another systematically but erratic little things with fuzzy edges and minds of their own. Newton's ordered universe is dead.

This is not news to me. I am self-employed, and I live with cats. But for those who find uncertainty hard to grasp, the theoretical physicist Erwin Schrödinger some years ago illustrated it with a thought experiment, the famous Schrödinger's Cat:

In a box, place a bit of radioactive material, a Geiger counter, a canister of poison gas, and a charge device. Connect the Geiger counter to the charge device and the device to the canister, so that if a particle emitted from the radioactive source hits the Geiger counter, it triggers the charge, blows the cap on the canister, and releases the poison gas. Into this arrangement, drop a live cat. Close the box, and leave for an hour. When you return, will you have a live cat or a dead one? There is no way to tell in advance, the emission of radioactive particles being random.

What a pathetically limited view of uncertainty! Imagine if Schrödinger had taken into account the documented facts about cat molecules:

1. Cat molecules have been known for centuries to be fuzzy around the edges and highly unpredictable.

2. A majority of cat molecules enjoys taking off in the same direction at the same time—enough, at least, to propel the entire cat mass across a room at slightly less than the speed of light.

3. A significant minority of cat molecules is governed by the scientific principle of contrariness. When the majority of cat molecules starts moving in one direction, the contrarion molecules rush headlong in another.

4. The motion of a cat mass, then, is the sum of the vectors of warring molecules. Thus the direction in which a cat mass will travel is entirely unpredictable.

5. All cat molecules become extremely agitated at the prospect of confinement in a box.

Add these facts to Schrödinger's experiment and you can begin to appreciate uncertainty. For example, most cat molecules know who their friends are, and we can assume that Schrödinger is not among them. How long will it take him to capture the cat molecules and jam them into the box? We cannot predict.

For the sake of argument, however, let's say it takes four hours–an optimistic estimate, considering that Schrödinger will have to stop for first aid, possibly a transfusion. What if some radioactive particle takes off before the cat molecules can be introduced? Surely Schrödinger has armed the poison gas mechanism in advance, since once any cat mass is dropped into a box, slamming and securing the lid is the only priority. But what if he left the lid open while pursuing the cat molecules? Is the gas poisonous to humans? When Mrs. Schrödinger comes to summon her husband to lunch, will she find a live Schrödinger or a dead one? It is impossible to tell.

But let's assume that Schrödinger survives and gets the cat molecules into the box. Say he goes away to work on his next project (something involving live grenades and golden retriever puppies) and returns in an hour. Say he finds a pile of dead cat molecules. What does that prove? That it all went as planned—the random particle took off, the trigger worked, the cap blew, and the cat molecules gasped and died?

This hypothesis seems to assume that the cat molecules went to sleep the instant the lid snaps shut. How probable is that? Might not the cat molecules have attacked the Geiger counter or tried to snap the gas canister's neck? Couldn't they have died of fright? And what about the effect of cat urine on the charge device?

Or let's say the cat molecules survive. Can we predict what will happen when Schrödinger opens the box? The effect of confinement on cat molecules is well known. Odds are that when the box is opened, the cat molecules will instantly launch the cat mass directly at Schrödinger's eyes. But the cat molecules might target a more vulnerable part of Schrödinger's anatomy. It's impossible to say.

Schrödinger's Cat clearly shows that Schrödinger was a pathologically orderly man. The uncertainty principle filled him with fear and loathing–and so, of course, did cats. He did, however, get along reasonably well with Mrs. Schrödinger. Otherwise, we would have Schrödinger's Wife. And there's no telling what that thought experiment might have illuminated, no telling at all.

–Carole Simon

Board Games

Photo:Ken Cole

About 120 physicists gathered at APS headquarters in December to sort the almost 7000 abstracts submitted to the APS March Meeting that will take place in Denver, March 5-9. Action around the big board got rather intense as representatives of the different divisions, topical groups and forums jockeyed for position. In the end, though, no one was seriously injured, all the sessions were filled, and another March Meeting was well on its way to success.

Physics News in 2006

A Supplement to *APS News*

Edited by Phil Schewe, Ben Stein and Ernie Tretkoff

Introduction

Physics News in 2006, a summary of physics highlights for the past year, was compiled from items appearing in AIP's weekly newsletter *Physics News Update*, written by Phil Schewe and Ben Stein. The items in this supplement were compiled by Ernie Tretkoff of the American Physical Society. The items below are in no particular order. Because of limited space in this supplement, some physics fields and certain contributions to particular research areas might be underrepresented in this compendium.These items mostly appear as they did during the year, and the events reported therein may in some cases have been overtaken by newer results and newer publications which might not be reflected in the reporting. Readers can get a fuller account of the year's achievements by going to the *Physics News Update* website at http://www.aip.org/physnews/update and APS's *Physical Review Focus* website at http://focus.aps.org/.

Plumbing the Electron's Depths

Careful observation of a single electron in an atom trap over a period of several months has resulted in the best measurement yet of the electron's magnetic moment and an improved value for alpha, the fine structure constant, the parameter which sets the overall strength of the electromagnetic force.

The theory of quantum electrodynamics (QED) predicts that an electron is perpetually grappling with virtual particles emerging briefly from the surrounding vacuum.

In the absence of these interactions, the magnetic moment of the electron (referred to by the letter *g*), which relates the size of the electron's magnetism to its intrinsic spin, would have a value of 2. But direct measurements of *g* show that it is slightly different from 2. The finer these measurements become, the better one can probe the quantum nature of electrons and QED itself. Furthermore, if the electron had structure this too would show up in measurements of *g*.

To gain the greatest possible control over the electron and its environment, Gerald Gabrielse and his students Brian Odom and David Hanneke at Harvard University create a macroscopic artificial atom consisting of a single electron executing an endless looping trajectory within a trap made of charged electrodes–a central, positively-charged electrode and two negatively-charged electrodes above and below–supplemented by coils producing a magnetic field. The combined electric and magnetic forces keep the electron in its circular "cyclotron" orbit. In addition to this planar motion, the electron wobbles up and down in the vertical direction, the direction of the magnetic field. The heart of the Harvard experiment is to explore these two motions–the circular motion, which conforms to quantum rules, and the vertical motion, which conforms to classical physics–in a new way.

It is this masterful control over the electron's motions and the ability to measure the energy levels of the electron's artificial quantum environment that allows the Harvard group to improve the measurement of *g* by a factor of 6 over previous work. The new uncertainty in the value, set forth in an article in *Physical Review Letters*, is now at the level of 0.76 parts per trillion.

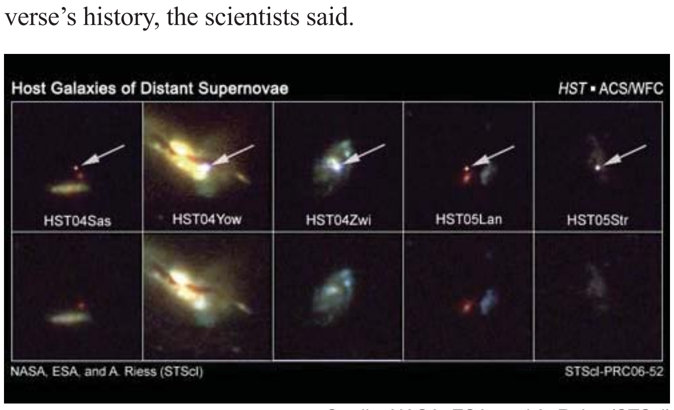
No less important than *g* is alpha. By inserting the new value of *g* into QED equations, and thanks to improved QED calculations of very high accuracy, the experimenters and theorists together determined a new value for alpha, one with an accuracy ten times better than available from any other method. This is the first time a more precise value of alpha has been reported since 1987. The new alpha, published in a companion article in *Physical Review Letters*, has an uncertainty of 0.7 parts per billion.

The measured value of *g* can also be used to address the issue of hypothetical electron constituents. Such subcomponents, the new g measurement shows, could be no lighter than 130 gigaelectronvolt.

According to Gabrielse, an improved value for alpha should, among other things, contribute to the pending adjustment of fundamental constants aimed at redefining the kilogram in a way that avoids the use of an actual weight kept under glass in Paris. (Odom et al., *Phys. Rev. Lett.* 97, 030801, 2006) and Gabrielse et al., *Phys. Rev. Lett.* 97, 030802, 2006)

Dark Energy at Redshift Z=1

Dark energy, the unidentified force that's pushing the universe to expand at ever faster rates, was already at work as early as nine billion years ago, scientists reported in November. New Hubble Space Telescope sightings of distant supernova explosions support the explanation of dark energy as energy of the vacuum whose density has stayed constant throughout the universe's history, the scientists said.



Credit: NASA, ESA, and A. Reiss (STScI)

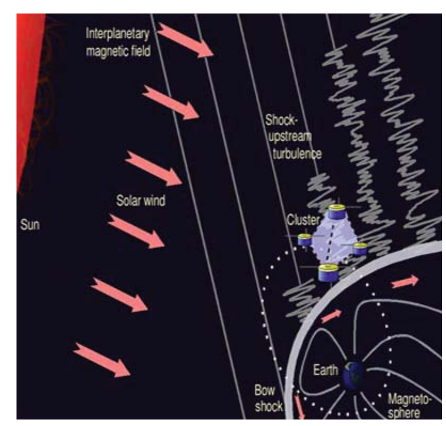
Using the Hubble, a team led by Adam Riess, an astrophysicist at the Space Telescope Science Institute and at Johns Hopkins University has now observed 23 new supernovae dating back to 8 to 10 billion years ago. Until now, astronomers had only seen seven supernovae from that period, Riess said, too few to measure the properties of dark energy. The data show that the repulsive action of dark energy was already active at that time, and are consistent with a constant energy density–in other words, with an energy of the vacuum that does not dilute itself as the universe expands, eventually fueling an exponential growth of the universe.

More complicated models with non-constant energy density–including a class known as quintessence models–are not completely ruled out, Riess said during the press conference: the new data still allows for variations of up to 45 percent from constant density. For more recent ages, dark energy is known to have been constant up to a 10 percent variation.

The new data also confirm the reliability of supernovae as signposts of the universe's expansion, Riess said.

First Direct Evidence of Turbulence in Space

Turbulence can be studied on Earth easily by mapping such things as the density or velocity of fluids in a tank. In space, however, where we expect turbulence to occur in such settings as solar wind, interstellar space, and the accretion disks around black holes, it's not so easy to measure fluids in time and space. Now, a suite of four plasma-watching satellites, referred to as Cluster, has provided the first definitive study of turbulence in space.



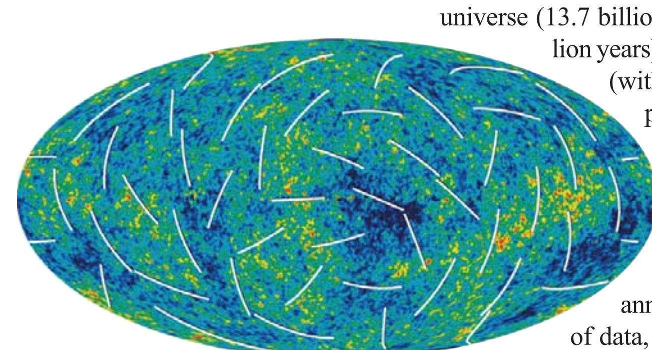
The fluid in question is the wind of particles streaming toward Earth from the sun, while the location in question is the region just upstream of Earth's bow shock, the place where the solar wind gets disturbed and passes by Earth's magnetosphere The waves in the shock-upstream plasma, pushed around by complex magnetic fields, are observed to behave a lot like fluid turbulence on Earth.

One of the Cluster researchers, Yasuhito Narita of the Institute of Geophysics and Extraterrestrial Physics in Braunschweig, Germany, says that the data is primarily in accord with the leading theory of fluid turbulence, the so-called Kolmogorov's model. (Narita et al., *Phys. Rev. Lett.* 97, 191101, 2006)

A New Triumph for Inflation

The inflationary big bang model has passed a crucial test as scientists working on the Wilkinson Microwave Anisotropy Probe released a long-awaited second set of data at a press conference held March 17.

The earlier release of WMAP data 3 years ago nailed down several grand features of the universe that had previously been known only very roughly, including: the time of recombination (380,000 years after the big bang, when the first atoms were formed); the age of the universe (13.7 billion years, plus or minus 200 million years); and the makeup of the universe (with dark energy accounting for 73 percent of all energy).



Credit: NASA/WMAP Science Team

Since that 2003 announcement, WMAP researchers have painstakingly worked to reduce the uncertainties in their results. The new result in the March 17 announcement, based on three years of data, was the release of a map of the sky containing information about the microwaves' polarization.

The microwaves are partly polarized from the time of their origin (emerging from the so-called sphere of last scattering) and partly polarized by scattering, on their journey to Earth, from the pervasive plasma of mostly ionized hydrogen created when ultraviolet radiation from the first generation of stars struck surrounding interstellar gas.

WMAP now estimates that this reionization, effectively denoting the era of the first stars, occurred 400 million years after the big bang, instead of 200 million years as had been previously thought. The main step forward is that smaller error bars, courtesy of the polarization map and the much better temperature map across the sky–with an uncertainty of only 200 billionth of a Kelvin–provide a new estimate for the inhomogeneities in the CMB's temperature.

The simplest model, called Harrison-Zeldovich, posits that the spectrum of inhomogeneities should be flat; that is, the inhomogeneities should have the same variation at all scales. Inflation, on the other hand, predicts a slight deviation from this flatness.

The new WMAP data for the first time measures the spectrum with enough precision to show a preference for inflation rather than the Harrison-Zeldovic spectrum–a test that was long-awaited as inflation's smoking gun. (Papers available on the NASA webpage: http://map.gsfc.nasa.gov/m_mm/pub_papers/threeyear.html)

Two-Dimensional Light

Two-dimensional light, or plasmons, can be triggered when light strikes a patterned metallic surface. Plasmons may well serve as a proxy for bridging the divide between photonics (high throughput of data but also at the relatively large circuit dimensions of one micron) and electronics (relatively low throughput but tiny dimensions of tens of nanometers, or millionths of a millimeter).

One might be able to establish a hybrid discipline, plasmonics, in which light is first converted into plasmons, which then propagate in a metallic surface but with a wavelength smaller than the original light; the plasmons could then be processed with their own two-dimensional optical components (mirrors, waveguides, lenses, etc.), and later plasmons could be turned back into light or into electric signals.

To show how this field is shaping up, here are a few plasmon results from the APS March Meeting.

1. *Plasmons in biosensors and cancer therapy:* Naomi Halas described how plasmons excited in the surface of tiny gold-coated, rice-grain-shaped particles can act as powerful, localized sources of light for doing spectroscopy on nearby bio-molecules. The plasmons' electric fields at the curved ends of the rice are much more intense than those of the laser light used to excite the plasmons, and this greatly improves the speed and accuracy of the spectroscopy. Tuned a different way, plasmons on nanoparticles can be used not just for identification but also for the eradication of cancer cells in rats.

2. *Plasmon microscope:* Igor Smolyaninov reported that he and his colleagues were able to image tiny objects lying in a plane with spatial resolution much better than diffraction would normally allow; furthermore, this is far-field microscopy–the light source doesn't have to be located less than a light-wavelength away from the object. They use 2D plasmon mirrors and lenses to help in the imaging and then conduct plasmons away by a waveguide.

3. *Photon-polariton superlensing and giant transmission:* Gennady Shvets reported on his use of surface phonons excited by light to achieve super-lens (lensing with flat-panel materials) microscope resolutions as good as one-twentieth of a wavelength in the mid-infrared range of light. He and his colleagues could image subsurface features in a sample, and they observed what they call "giant transmission," in which light falls on a surface covered with holes much smaller than the wavelength of the light. Even though the total area of the holes is only 6 percent of the total surface area, 30 percent of the light got through, courtesy of plasmon activity at the holes.

4. *Future plasmon circuits at optical frequencies:* Nader Engheta argued that nano-particles, some supporting plasmon excitations, could be configured to act as nm-sized capacitors, resistors, and inductors–the basic elements of any electrical circuit.

The circuit in this case would be able to operate at optical (10^{15} Hz) frequencies. This would make possible the miniaturization and direct processing of optical signals with nano-antennas, nano-circuit-filters, nano-waveguides, nano-resonators, and may lead to possible applications in nano-computing, nano-storage, molecular signaling, and molecular-optical interfacing.

Nanotubes Unfolded

Two-dimensional carbon, or graphene, has many of the interesting properties possessed by one-dimensional carbon (in the form of nanotubes): electrons can move at high speed and suffer little energy loss. According to Walt deHeer (Georgia Tech), who spoke at the APS March Meeting in Baltimore, graphene will provide a more controllable platform for integrated electronics than is possible with nanotubes, since graphene structures can be fabricated lithographically as large wafers.

Single sheets of graphene were isolated in 2004 by Andre Geim (University of Manchester). In graphene, electron velocity is independent of energy. That is, electrons move as if they were light waves. This extraordinary property was elucidated in November 2005 through experiments using the quantum Hall effect (QHE), in which electrons, confined to a plane and subjected to high magnetic fields, execute only prescribed quantum trajectories. These tests were conducted by groups represented at the APS meeting by Geim and Philip Kim (Columbia University).

The QHE studies also revealed that when an electron completes a full circular trajectory in the imposed magnetic field, its wavefunction is shifted by 180 degrees. This modification, called "Berry's phase," acts to reduce the propensity for electrons to scatter in the backwards direction; this in turn helps reduce electron energy loss.

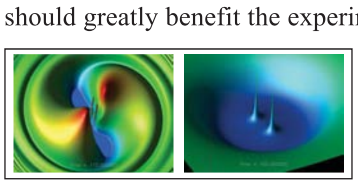
Geim reported a new twist to this story. Studying QHE in graphene bilayers he observed a new version of QHE, featuring a doubled Berry's phase of 360 degrees.

The goal now is to learn more graphene physics. For example, Walt DeHeer reported that a plot of resistance versus applied magnetic field had a fractal shape. DeHeer said that so far there is no explanation for this. As for applications, he said that on an all-graphene chip, linking components with the usual metallic interconnects, which tends to disrupt quantum relations, would not be necessary.

DeHeer's group so far has been attempting to build circuitry in this way; they have made graphene structures (including a graphene transistor) as small as 80 nanometers and expect to get down to the 10-nanometer size.

Black Hole Merger Movie

Accurate calculations of the gravitational waveforms emitted during the collision of black holes can now be made. A new computer study of how a pair of black holes, circling each other, disturbs the surrounding space and sends huge gusts of gravitational waves outwards, should greatly benefit the experimental search for those waves with detectors such as the Laser Interferometer Gravitational-Wave Observatory (LIGO) and the planned Laser Interferometer Space Antenna (LISA).



Black holes encapsulate the ultimate in gravitational forces, and this presents difficulties for computations attempting to model behavior nearby. Nevertheless, some physicists at the University of Texas at Brownsville have now derived an algorithm that not only produces accurate estimates of the gravity waves of the inspiraling black holes, even over the short time intervals leading up to the final merger, but also is easily implemented on computers.

"The importance of this work," says Carlos Lousto, one of the authors of the new study, "is that it gives an accurate prediction to the gravitational wave observatories, such as LIGO, of what they are going to observe." The new results are part of a larger study of numerical relativity carried out at the University of Texas, work referred to as the Lazarus Project (Campanelli, Lousto, Marronetti, and Zlochower, *Phys. Rev. Lett.* 96, 111101, 2006)

In Protons, Virtual Strange Quarks Less Prevalent than Thought

The sea of virtual quarks shimmering inside every proton inside every atom has now been studied with exquisite precision in a new experiment conducted at the Thomas Jefferson National Accelerator Facility in Newport News, VA. The surprising result is that the quark-antiquark pairs bubbling irrepressibly into and out of existence, especially those with a strange flavor, contribute so little to the life of the proton, prompting theorists to puzzle even more intently over the basic question: what is a proton? The simple answer has been that the proton consists of three regular (valence) quarks always present plus the effervescent "sea quarks" emerging from the vacuum plus a fleet of force-carrying gluons. But if ever the whole did not equal the sum of its parts, this is true for the proton. Sum the charge of the valence quarks and you get the charge of the proton. So far, so good.

But sum the mass of the valence quarks and you account for less than 1 percent of the proton's mass. The Hall A Proton Parity Experiment (HAPPEx) at Jefferson Lab scatters a 3-gigaelectronvolt beam of electrons from a slender thermos bottle of liquid hydrogen, providing in effect a target full of protons, and from a helium target, which provides both protons and neutrons. Only those events in which the electron scatters elastically are chosen for analysis.

By controlling the polarization of the electrons, and by comparing the proton and helium scattering data, one can determine separately the contributions from electric, magnetic, and weak-force scattering. And from these, the degree to which sea quarks are present in the proton can be deduced.

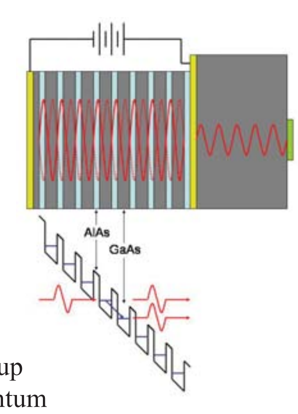
Previous theories, supported by some rough experimental evidence, supported the idea that strange quarks could account for as much as 10 percent of the proton's magnetic moment.

One of the HAPPEx scientists, Paul Souder of Syracuse University in Syracuse, N.Y., reported at the April Meeting in Dallas that, with much greater precision, strange quarks can account for about 1 percent of the proton's charge and no more than 4 percent of its magnetic moment, and that owing to experimental uncertainties both of these measured values might be consistent with zero. In other words, the proton is a lot less strange than thought.

A New Kind of Acoustic Laser

Sound amplification by stimulated emission of radiation, or SASER, is the acoustic analog of a laser. Instead of a feedback-built potent wave of electromagnetic radiation, a saser would deliver a potent ultrasound wave.

The concept has been around for years and several labs have implemented models with differing features. In a new version, undertaken by scientists from the University of Nottingham in the U.K. and the Lashkarev Institute of Semiconductor Physics in Ukraine, the gain medium–that is, the medium where the amplification takes place–consists of stacks (or a superlattice) of thin layers of semiconductors which together form "quantum wells."



In these wells, really just carefully confined planar regions, electrons can be excited by parcels of ultrasound, which typically possess millielectronvolts of energy, equivalent to a frequency of 0.1-1 terahertz. Just as coherent light can build up in a laser by the concerted, stimulated emission of light from a lot of atoms, so in a saser coherent sound can build up by the concerted emission of phonons from a lot of quantum wells in the superlattice.

In lasers the light buildup is maintained by a reflective optical cavity. In the U.K.-Ukraine saser, the acoustic buildup is maintained by an artful spacing of the lattice layer thicknesses in such a way that the layers act as an acoustic mirror.

Eventually the sound wave emerges from the device at a narrow angular range, as do laser pulses. The monoenergetic nature of the acoustic emission, however, has not yet been fully probed. The researchers believe their saser is the first to reach the terahertz frequency range while using also modest electrical power input. Terahertz acoustical devices might be used in modulating light waves in optoelectronic devices. (Kent et al., *Phys. Rev. Lett.* 96, 215504, 2006)

A Hint of Negative Electrical Resistance

A hint of negative electrical resistance emerges from a new experiment in which microwaves of two different frequencies are directed at a 2-dimensional electron gas. The electrons, moving at the interface between two semiconductor crystals, are subjected to an electric field in the forward (longitudinal) direction and a faint magnetic field in the direction perpendicular to the plane. In such conditions the electrons execute closed-loop trajectories which will, in addition, drift forward depending on the strength of the applied voltage.

A few years ago, two experimental groups observed that when, furthermore, the electrons were exposed to microwaves, the overall longitudinal resistance could vary widely–for example, increasing by an order of magnitude or extending down to zero, forming a zero-resistance state, depending on the relation between microwave frequency and the strength of the applied magnetic field.

Some theorists proposed that in such zero-resistance states, the resistance would actually have been less than zero: the swirling electrons would have drifted backwards against the applied voltage. However, this rearwards motion would be difficult to observe because of an instability in the current flow.

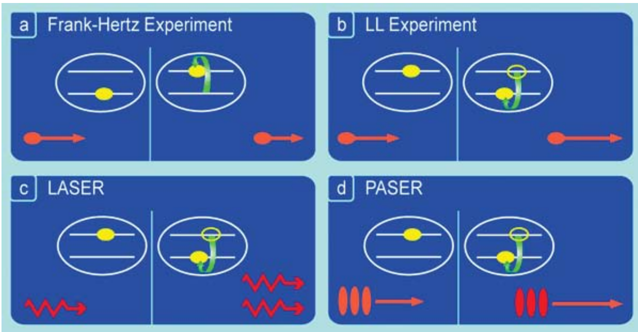
A Utah/Minnesota/Rice/Bell Labs group has now tested this hypothesis in a clever bichromatic experiment using microwaves at the two frequencies. Michael Zudov and Rui-Rui Du sent microwaves of two different frequencies at the electrons, observing that for nonzero-resistance states the resultant resistance was the average of the values corresponding to the two frequencies separately. On the other hand, when the measurements included frequencies that had yielded a zero resistance, the researchers observed a dramatic reduction of the signal.

Judging from the average resistance observed for non-zero measurements, they deduce that whenever zero resistance was detected, the true microscopic resistance had actually been less than zero. (Zudov et al., *Phys. Rev. Lett*. 96, 236804, 2006)

Particle Acceleration by Stimulated Emission of Radiation–PASER for Short

Particle Acceleration by Stimulated Emission of Radiation (PASER for short), a sort of particle analog of the laser process, has been demonstrated, for the first time, by a team of physicists from the Technion-Israel Institute of Technology using the accelerator facilities at the Brookhaven National Lab.

In a regular laser, photons traveling through an active medium (a body of excited atoms) will stimulate the atoms, through collisions, to surrender their energy in the form of additional emitted photons; this coherent process builds on itself until a large pulse of intense light exits the cavity in which the amplification takes place. In the new proof-of-principle PASER experiment, the active medium consists of a CO_2 vapor, and instead of surrendering their energy in the form of stimulated photons, the atoms transfer their energy to a beam of electrons.



The electrons stimulate the atoms into giving up their surplus energy through collisions. The electrons' energy is amplified in a coherent way. Although millions of collisions are involved for each electron, no heat is generated. The transferred energy goes into an enhanced electron motion. One could say that here was a laser which produced no laser light, only a laser-like transfer of energy resulting in electron acceleration. It should be said that the electrons began with an energy of 45 million electron volts (MeV) and absorbed only a modest energy of about 200 thousand electron volts (keV).

Being able to accelerate electrons with energy stored in individual atoms/molecules, a concept now demonstrated with the PASER, provides new opportunities since the accelerated electrons may prove to be significantly "cooler" (they are more collimated in velocity) than in some other prospective acceleration schemes, enabling in turn the secondary generation of high-quality X-rays, which are an essential tool in nano-science. (Banna, Berezovsky, Schachter, *Phys. Rev. Lett*. 97, 134801, 2006)

Hypersound

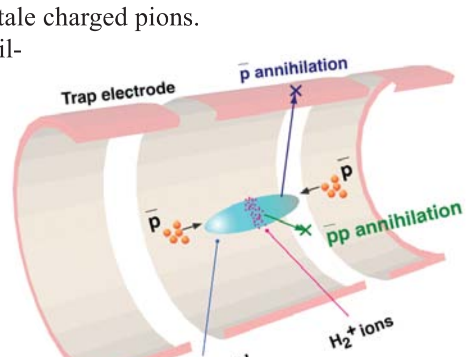
Hypersound, acoustic pulsation at 200 gigahertz frequencies, has been produced in the same kind of resonant multilayered semiconductor cavity as used in photonics. Physicists at the Institute des Nanosciences de Paris (France) and the Centro Atomico Bariloche and Instituto Balseiro (Argentina) generate the high frequency sound pulses in a solid material made of thin gallium arsenide and aluminum arsenide layers. One can picture the sound, excited by a femtosecond laser, as being a short pulse of waves or equivalently as particle-like phonons, excitations pulsing through the stack of layers. These phonons are reflected at either end of the device, called a nanocavity, by further layers with a much different acoustic impedance acting as mirrors. Acoustic impedance is the acoustic analog of the refractive index for light.

Bernard Jusserand says that he and his colleagues hope to reach the terahertz acoustic range. The wavelength for such "sound" is only nanometers in length. They believe that a new field, nanophononics, has been inaugurated, and that the acoustical properties of semiconductor nanodevices will become more prominent. THz phonons, and more specifically the reported nanocavities could, for example, be used to modulate the flow of charges or light at high frequency and in small spaces. THz sound might also participate in the development of powerful "acoustic lasers" or in novel forms of tomography for imaging the interior of opaque solids. (Huynh et al., *Phys. Rev. Lett*. 97, 115502, 2006)

First Antimatter Chemistry

The Athena collaboration, an experimental group working at the CERN laboratory in Geneva, has measured chemical reactions involving antiprotonic hydrogen, a bound object consisting of a antiproton paired with a proton.

This composite object, which can also be called protonium, eventually annihilates itself, creating an even number of telltale charged pions. Normally the annihilation comes about in a trillionth of a second, but in the Athena apparatus the duration is a whopping millionth of a second.



The protonium comes about in the following way. First, antiprotons are created in CERN's proton synchrotron by smashing protons into a thin target. The resultant antiprotons then undergo the deceleration, from 97 percent down to 10 percent of the speed of light. Several more stages of cooling bring the antiprotons to a point where they can be caught in Athena's electrostatic trap. This allows the researchers to study then, for the first time, a chemical reaction between the simplest antimatter ion–the antiproton–and the simplest matter molecular ion, namely H_2^+ (two hydrogen atoms with one electron missing). Joining these two ions results in the protonium plus a neutral hydrogen atom.

This represents the first antimatter-matter chemistry, if you don't count the interaction of positrons with ordinary matter. According to Nicola Zurlo of the Università di Brescia and his colleagues, the experimental output from the eventual protonium annihilation allowed the Athena scientists to deduce that the principal quantum number of the protonium had an average value of 70 rather than the expected value of 30. Furthermore, the angular momentum of the protonium was typically much lower than expected–perhaps because of the low relative velocity at which the matter and antimatter ions approached each other before reaction.

The Athena scientists hope to perform more detailed spectroscopy on their proton-antiproton "atom" in addition to the already scheduled spectroscopy of trapped anti-hydrogen atoms, which consist of antiprotons wedded to positrons. (Zurlo et al., *Phys. Rev. Lett.* 97, 153401, 2006)

Elements 116 and 118 Are Discovered

At the Joint Institute for Nuclear Research (JINR) in Dubna, Russia, physicists (including collaborators from Lawrence Livermore National Lab in the United States) have sent a beam of calcium-48 ions into a target of californium-249 atoms to create temporarily a handful of atoms representing element 118. The nuclei for these atoms have an atomic mass of 294 units.

In fact, only three of these atoms, the heaviest ever produced in a controlled experiment, were observed. After sending 2 x 10^{19} calcium projectiles into the target, one atom of element 118 was discovered in the year 2002 and two more atoms in 2005. The researchers held up publication after seeing their first specimen in order to find more events. According to Livermore physicist Ken Moody, the three events have been well studied and the odds of a statistical fluke at work here are less than a part in 100 thousand.

Caution would naturally be on the minds of anyone announcing a new element. Evidence for element 118 was offered once before, by a team at the Lawrence Berkeley National Laboratory, but this claim was later retracted when it was discovered that some of the data had been falsified.

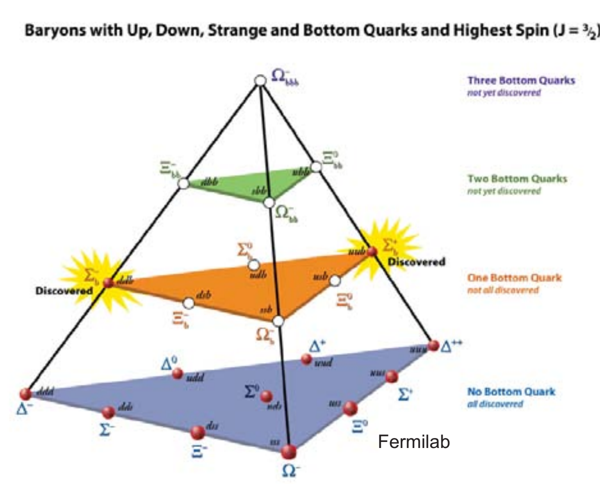
In searching through 10^{19} collision events, how do you know you have found a new element? Because of the clear and unique decay sequence involving the offloading of alpha particles. In this case, nuclei of element 118 decay to become element 116 (hereby itself discovered for the first time), and then element 114, and then element 112 by emitting detectable alphas. The 112 nucleus subsequently fissions into roughly equal-sized daughter particles.

The average lifetime observed for the three examples of element 118 was about one millisecond, not long enough to perform any kind of chemical tests. Element 118 lies just beneath radon in the periodic table and is therefore a kind of noble gas.

The Dubna-Livermore team previously announced the discovery of elements 113 and 115 and next hope to produce element 120 by crashing a beam of iron atoms into a plutonium target. (Oganessian et al., *Phys. Rev.* C 74, 044602, 2006)

New Baryons Discovered

The periodic table of baryons has now been supplemented with several heavyweight members. The new members of the baryonic periodic table are unstable and ephemeral, but their observed existence serves to expand our understanding of matter in the universe. The new baryons, the heaviest yet with masses around 5.8 gigaelectron-volt, were sifted from trillions of proton-antiproton collisions conducted at an energy of 2 tera-electronvolts at the Fermilab.



Up to now there was only one well established bottom-quark-bearing baryon, the so called Lambdab. The first evidence for its existence was reported by CERN and Fermilab in late 1990s based on a handful of events. Now the CDF collaboration at Fermilab is claiming discovery of two baryon types, each on the basis of about 100 events. Actually there are four new so-called Sigma_b baryons: two positively charged baryons with a u-u-b combination (one with spin 1/2, one with spin 3/2), the first of which constitutes a sort of bottom-proton; and two negatively charged baryons with a d-d-b combination (one each with a spin of 1/2 or 3/2). In all cases, the Sigma decays almost immediately into a Lambda_b particle (with a u-d-b set of quarks) plus a pion. In the detector the Lambda typically flies about 100 microns before decaying into Lambda_c (a Lambda baryon with a c quark instead of a b), which quickly decays into an ordinary proton.

The new results were announced at a talk at Fermilab by Petar Maksimovic, of Johns Hopkins University. Jacobo Konigsberg, of the University of Florida, the co-spokesperson for the CDF group says that the statistical odds against the Sigmab particles being real are at the level of a few parts in 10^{19}. (for more information see Fermilab press release: http://www.fnal.gov/pub/presspass/press_releases/sigma-b-baryon.html)

Have Particle Masses Changed since the Early Universe?

Indications of a change in the proton-to-electron mass ratio have shown up in comparisons of the spectra of hydrogen gas as recorded in a lab with spectra of light coming from hydrogen clouds at the distance of quasars. This is another of those tests of so-called physical constants that might not be absolutely constant.

The proton-to-electron mass ratio (denoted by the letter mu) figures in setting the scale of the strong nuclear force.

There is at present no explanation why the proton's mass should be 1,836 times that of the electron. The new search for a varying mu was carried out by Wim Ubachs of the Vrije Universiteit Amsterdam. He and his colleagues studied hydrogen gas in the lab, performing ultra-high-resolution spectroscopy in the difficult-to-access extreme-ultraviolet range. This data is compared to accurate observations of absorption spectra of distant hydrogen (which absorbs light from even more distant quasars) as recorded with the European Southern Observatory (ESO) in Chile.

The astronomical hydrogen is essentially hydrogen as it was 12 billion years ago, so one can seek hints of a changing value for mu. The position of a particular spectral line depends on the value of mu; locate the spectral line accurately and you can infer a value for mu. In this way, the researchers report that they see evidence that mu has decreased by 0.002 percent over those 12 billion years. According to Ubachs, the statistical confidence of his spectroscopic comparison is at the level of 3.5 standard deviations. (Reinhold et al., *Phys. Rev. Lett*. 96, 151101, 2006)

A Baby Picture That's Worth a Nobel Prize

The 2006 Nobel Prize for Physics was awarded to John Mather of NASA/Goddard Space Flight Center and George Smoot of the University of California, Berkeley and Lawrence Berkeley National Laboratory. They are cited for the study of the early universe. They were instrumental in developing the Cosmic Background Explorer (COBE) experiment. This orbiting spacecraft was the first to detect faint temperature variations in the cosmic microwave background (CMB), the bath of radiation representing the first light able to move freely through the universe after the big bang. COBE's map of these temperature variations across the whole sky has been called the earliest "baby picture" we have of our universe.

The CMB was initially observed in the 1960s by Arno Penzias and Robert Wilson at Bell Labs, in New Jersey, for which they would later receive the Nobel Prize. It was thought at the time that the CMB would be least somewhat inhomogeneous since the subsequent galaxies we now see would have to form from slight imbalances of matter in the pervasive hot plasma that constituted the substance of the universe (as far as we know) just before the first atoms formed. But how big those clumps of matter were, showing up as slight temperature variations in the map of the CMB across the sky, was unknown.

At a press conference at the American Physical Society April meeting in 1992, COBE speakers, including Smoot and Mather, announced the discovery of variations at the level of parts per hundred thousand against an overall average temperature of 2.7 degrees Kelvin.

The microwave background is in effect the biggest thing we can see (indeed it spreads out across the whole sky), the farthest-out thing we can map, and the furthest-back in time. COBE was the first to measure the variations and the first to provide a really precise average temperature for the universe, 2.726 degrees Kelvin. The COBE work represented a feat of great experimental science since the faint variations in the temperature of the distant CMB had to be measured against a foreground cloud of microwave radiation coming from our solar system, our galaxy, and other celestial objects.

Later CMB detectors, including the balloon-borne Boomerang and the land-based Degree Angular Scale Interferometer (DASI), added more and more detail to the microwave background.

The most recent and best microwave measurements have been presented by the WMAP detector, which provides the clearest multipole curve yet as well as supplying the best values for important cosmological parameters such as the age of the universe, the overall curvature of spacetime, and the time when the first atoms formed and the first stars.

Attack of the Teleclones

Should quantum cryptographers begin to worry? In contrast with everyday matter, quantum systems such as photons cannot be copied, at least not perfectly, according to the "no-cloning theorem." Nonetheless, imperfect cloning is permitted, so long as Heisenberg's Uncertainty Principle remains inviolate.

Now, quantum cloning has been combined with quantum teleportation in the first full experimental demonstration of "telecloning" by scientists at the University of Tokyo, the Japan Science and Technology Agency, and the University of York. In ideal teleportation, the original is destroyed and its exact properties are transmitted to a second, remote particle; the Heisenberg principle does not apply because no definitive measurements are made on the original particle. In telecloning, the original is destroyed, and its properties are sent to not one but two remote particles, with the original's properties reconstructed to a maximum accuracy (fidelity) of less than 100 percent.

In their experiment, the researchers didn't just teleclone a single particle, but rather an entire beam of laser light. They transmitted the beam's electric field, specifically its amplitude and phase–but not its polarization–to two nearly identical beams at a remote location with 58 percent accuracy or fidelity, out of a theoretical limit of 66 percent.

Telecloning stands apart from local cloning and from teleportation in requiring "multipartite" entanglement, a form of entanglement in which stricter correlations are required between the quantum particles or systems, in this case three beams of light.

In addition to representing a new quantum-information tool, telecloning may have an exotic application: tapping quantum cryptographic channels. Quantum cryptographic protocols are so secure that they may discover tapping. Nonetheless, with telecloning, the identity and location of the eavesdropper could be guaranteed uncompromised. (Koike et al., *Phys. Rev. Lett.* 96, 060504, 2006)

Slow-Motion Boiling

A new study, carried out at a chilly temperature of 33 degrees Kelvin, explains why certain industrial heat exchangers (including those used at power plants) melt catastrophically when steam formation undergoes a process referred to as a "boiling crisis."

Boiling, a sort of accelerated evaporation, is usually a very efficient form of energy transfer because of the transport of latent heat (the heat required for a substance to change its phase); energy moves from a heater to a liquid by the formation of vapor bubbles. There can be an important hitch in this process, however, and that is the poorly understood boiling crisis.

This potentially dangerous situation comes about as follows: at high enough temperatures the formation of bubbles becomes so great that the entire surface of the heating element (the part of the heater in contact with the liquid) can be covered with a vapor film, which insulates the liquid above from absorbing heat. (Just as a water droplet, hitting a frying pan, evaporates only very slowly.) The result is a buildup of heat in the heater and possible meltdown.

What Vadim Nikolayev and his colleagues at the École Supérieure de Physique et de Chimie Industrielles in Paris, Commission of Atomic Energy in Grenoble, and the University of Bordeaux have done is to provide the first detailed look at the boiling crisis by performing simulations and laboratory tests of a theory which suggests that the overheating comes about because of vapor recoil. That is, at high enough heat flux, the growing bubble will forcefully push aside liquid near the heating element, expanding the potentially dangerous insulating vapor layer.

This theory was upheld by experimental work performed not at the blazing temperature of high-pressure steam but near the chilly critical temperature of liquid hydrogen, where boiling would occur very slowly, in a way that could be glimpsed more completely. Thanks to the universality of fluid dynamics, however, lessons learned at 33 degrees Kelvin should be applicable to fluids at 100 degrees Celsius.

Nikolayev believes that better understanding of the boiling crisis will facilitate certain counter-measures. This is important since possible boiling problems occur not just at major industrial sites but also for such consumer electronic products as laptop computers, where soon the rate of heat dissipation will be much higher than for today's models owing to further miniaturization. (Nikolayev et al., *Phys. Rev. Lett.* 97, 184503, 2006)

GeV Acceleration in Only 3 Centimeters

Much of particle physics over the past century was made possible by machines that could accelerate particles up to energies of thousands of electronvolts (keV), then millions of electronvolts (MeV), and then billions (GeV). Possessing such high energies, beam particles can, when they smash into something, recreate for a short time a small piece of the early hot universe. Now the effort to impart more acceleration to particles over a short haul has taken a notable step forward. Physicists at the Lawrence Berkeley National Laboratory and the University of Oxford have accelerated electrons up to an energy of 1 GeV in a space of only 3 centimeters. The device used is called a laser wakefield accelerator since it boosts the electrons using potent electric fields set up at the trailing edge of a burst of laser light traveling through a plasma-filled cavity. Previously, gradients as high as 100 GeV per meter had been attained, but the acceleration process could not be sustained to energies much above 200 MeV. (Leemans et al., *Nature Physics*, October 2006)

Ellipsoidal Universe

A new theoretical assessment of data taken by the Wilkinson Microwave Anisotropy Probe (WMAP) suggests that the universe–at least that part of it that can be observed–is not spherically symmetric, but more like an ellipsoid.

The WMAP data has served to nail down some of the most important parameters in all of science. One remaining oddity about the WMAP results, however, concerns the way in which portions of the sky contribute to the overall map of cosmic microwaves; samples of the sky smaller than one degree across, or at the degree level, or tens of degrees seem to be contributing radiation at expected levels. Only the largest possible scale, that on the order of the whole sky itself (the technical term is quadrupole moment), seems to be under-represented.

Now Leonardo Campanelli of the University of Ferrara and his colleagues Paolo Cea and Luigi Tedesco at the University of Bari (all in Italy) have studied what happens to the quadrupole anomaly if one supposes that the shell from which the cosmic microwaves come toward earth is an ellipsoid and not a sphere. This shell is called surface of last scattering since it corresponds to that moment in history when photons largely stopped scattering from charged particles when it became cool enough for many of the particles to bundle themselves into neutral atoms. If the microwave shell is an ellipsoid with an eccentricity of about 1 percent, then the WMAP quadrupole is exactly what it should be.

This is not the first time a non-spherical universe has been suggested, but it is the first time the idea has been applied to the state-of-the-art WMAP data. What could have caused the universe as a whole to be ellipsoidal? Campanelli, Cea and Tedesco say that a uniform magnetic field pervading the cosmos, or a defect in the fabric of spacetime, could bring about a non-zero eccentricity. (Campanelli, Cea, and Tedesco, *Phys. Rev. Lett.* 97, 131302, 2006)

Atoms in a Trap Measure Gravity at the Micron Level

Nowadays many of the most sensitive measurements in science depend on some quantum phenomenon which very subtly can often be exploited to gain maximum precision. In an experiment conducted at the Università di Firenze (University of Florence), the quantum phenomenon in question is called Bloch oscillation. This weird effect occurs when particles subject to a periodic potential–such as electrons feeling the regular gridlike electric force of a crystalline lattice of atoms–are exposed to an additional static force, say, an electric force in a single direction; what happens is that the electrons do not all move in the direction of the force, but instead oscillate back and forth in place.

In a new experiment conducted by Guglielmo Tino and his Florence colleagues, the particles are supercold strontium atoms held in a vertically oriented optical trap formed by criss-crossing laser beams, while the static force is merely the force of gravity pulling down on the atoms.

Although Bloch oscillations have been observed before, they have never been sustained for as long as 10 seconds, which is the case here.

Close observation of the Bloch oscillations allows you to measure the strength of the static force, with high precision–in this case to measure gravity with an uncertainty of a part in a million.

With planned improvements to the apparatus, the researchers will be able to bring the atoms to within a few microns of a test mass and will measure g with an uncertainty of 0.1 parts per million. With these conditions, one can probe theories which say that gravity should depart from the Newtonian norm, perhaps signifying the existence of unknown spatial dimensions.

According to Tino, unlike gravity-measuring experiments which use torsional balances or cantilevers, the Florence approach measures gravity directly and over shorter distances. The atom-trap setup should also prove useful for future inertial guidance systems and optical clocks. (Ferrari et al., *Phys. Rev. Lett.* 97, 060402, 2006)

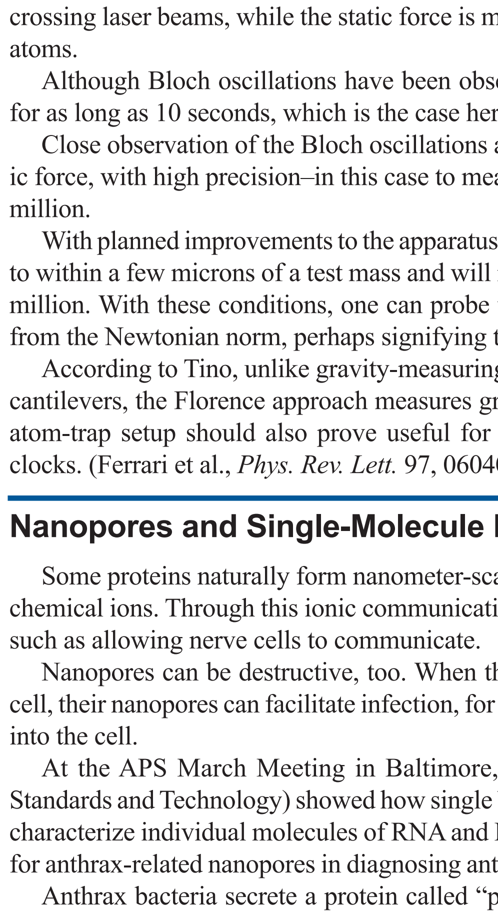
Nanopores and Single-Molecule Biophysics

Some proteins naturally form nanometer-scale pores that serve as channels for useful biochemical ions. Through this ionic communication, nanopores enable many functions in cells, such as allowing nerve cells to communicate.

Nanopores can be destructive, too. When the proteins of bacteria and viruses attach to a cell, their nanopores can facilitate infection, for example by shooting viral DNA through them into the cell.

At the APS March Meeting in Baltimore, John J. Kasianowicz (National Institute of Standards and Technology) showed how single biological nanopores can be used to detect and characterize individual molecules of RNA and DNA. He also demonstrated constructive uses for anthrax-related nanopores in diagnosing anthrax infections and testing anti-anthrax drugs.

Anthrax bacteria secrete a protein called "protective antigen" that attaches to an organic membrane such as a cell wall. The protein forms a nanopore that penetrates the membrane. When another anthrax protein, called "lethal factor," attaches to the protective antigen nanopore, it prevents ionic current from flowing through the pore and out of the organic membrane.



By monitoring animal blood samples for changes in ion current, Kasianowicz and his colleagues at the National Cancer Institute and the United States Army Medical Research Institute for Infectious Diseases electronically detected a complex of two anthrax proteins in less than an hour, as opposed to the existing methods which can take up to several days. Also, they demonstrated a method for screening potential therapeutic agents against anthrax toxins using the anthrax nanopore.

A Brown University group led by Sean Ling was among those reporting progress in developing a nanopore-based method for sequencing DNA faster and more cheaply than traditional biochemical techniques. In one scenario, the change in ion current as DNA moves through the nanopore could yield the sequence of bases in the DNA. However, the letters in DNA are so close to each other (about .4 nm), and the DNA moves so quickly through the nanopore, that researchers have had to come up with creative solutions for reading the individual letters. For example, the Brown group attaches complementary blocks of DNA, about six letters long, to the DNA sequence of interest, so that the researchers would read blocks of multiple letters at a time, while slowing down the passage of the DNA by attaching a magnetic bead to it.

Other researchers are finding value in developing nanopores for fundamental biology studies. Discussing his group's latest work with artificial, silicon-based nanopores, Cees Dekker of the Delft University of Technology in Delft, Holland showed how lasers and other manipulations with the artificial pores are enabling new single-molecule biophysics studies on the properties of DNA, RNA, and proteins by studying how they pass through the pores.

Dune Tunes

For centuries, world travelers have known of sand dunes that issue loud sounds, sometimes of great tonal quality. Now, a team of scientists has disproved the long held belief that the sound comes from vibrations of the dune as a whole and proven, through field studies and through controlled experiments in a lab, that the sounds come from the synchronized motions of the grains in avalanches of a certain size.

Small avalanches don't produce any detectable sound, while large avalanches produce sound at lots of frequencies (leading to cacophonous noise). But sand slides of just the right size and velocity result in sounds of a pure frequency, with just enough overtones to give the sound "color," as if the dunes were musical instruments. In this case, however, the tuning isn't produced by any outside influence but by critically self-organizing tendencies of the dune itself. The researchers thus rule out various "musical" explanations.

For example, the dune sound does not come from the stick-slip motion of blocks of sand across the body of the dune (much as violin sounds are made by the somewhat-periodic stick-slip motion of a bow across a string attached to the body of the violin). Nor does the dune song arise from a resonance effect (much as resonating air inside a flute produces a pure tone) since it is observed that the dune sound level can be recorded at many locations around the dune.

Instead, the sand sound comes from the synchronized, free sliding motion of dry larger-grained sand producing lower frequency sound. (Douady et al., *Phys. Rev. Lett.* 97, 018002, 2006)

Can String Theory Explain Dark Energy?

A new paper by Cambridge physicist Stephen Hawking and Thomas Hertog of CERN suggests that it can. The leading explanation for the observed acceleration of the expansion of the universe is that a substance, dark energy, fills the vacuum and produces a uniform repulsive force between any two points in space. Quantum field theory allows for the existence of such a universal tendency. Unfortunately, its prediction for the value the cosmological constant is some 120 orders of magnitude larger than the observed value.

In 2003, cosmologist Andrei Linde of Stanford University and his collaborators showed that string theory allows for the existence of dark energy, but without specifying the value of the cosmological constant. String theory, they found, produces a mathematical graph shaped like a mountainous landscape, where altitude represents the value of the cosmological constant. After the big bang, the value would settle on a low point somewhere between the peaks and valleys of the landscape. But there could be on the order of 10^{500} possible low points and no obvious reason for the universe to pick the one we observe in nature.

Some experts hailed this multiplicity of values as a virtue of the theory. But critics see the landscape as exemplifying the theory's inability to make useful predictions.

The Hawking/Hertog paper is meant to address this concern. It looks at the universe as a quantum system in the framework of string theory. In Richard Feynman's formulation of quantum theory, the probability that a photon ends up at a particular spot is calculated by summing up over all possible trajectories for the photon. Hawking and Hertog argue that the universe itself must also follow different trajectories at once, evolving through many simultaneous, parallel histories, or "branches."

But applying quantum theory to the entire universe is tricky. Here you have no control over the initial conditions, nor can your repeat the experiment again and again for statistical significance. Instead, the Hawking-Hertog approach starts with the present and uses what we know about our branch of the universe to trace its history backwards. Again, there will be multiple possible branches in our past, but most can be ignored in the Feynman summation because they are just too different from the universe we know.

For example, Hertog says, knowledge that our universe is very close to being flat could allow one to concentrate on a very small portion of the string theory landscape whose values for the cosmological constant are compatible with that flatness. That could in turn lead to predictions that are experimentally testable. For example, one could calculate whether our universe is likely to produce the microwave background spectrum we actually observe. (S. W. Hawking and Thomas Hertog *Phys. Rev*. D 73, 123527, 2006)

Testing Special Relativity and Newtonian Gravity

Lorentz invariance says that the laws of physics are the same for an observer at rest on Earth or one who is rotated through some angle or traveling at a constant speed relative to the observer at rest. Some researchers are looking for a crack in the universe in the form of a very faint field pervading the Cosmos, one that exerts a force on electron spin, which would mean the end of Lorentz invariance. A new experiment conducted at the University of Washington, in Seattle, has sought such an anomalous field and not found it even at an energy scale of 10^{-21} electronvolts. This is the most stringent search yet–by a factor of 100 –for Lorentz-invariance-violating effects involving electrons.

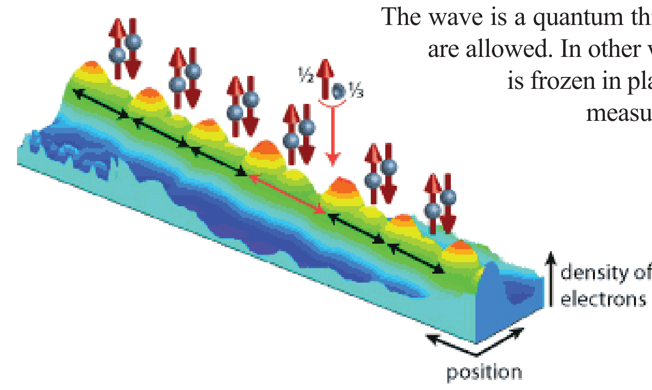
The Washington work, described at the APS April Meeting in Dallas by Claire Cramer, is part of an ongoing battery of tests carried out with a flexible and sophisticated torsion-balance apparatus. In this case, a pendulum is made of blocks whose magnetism arises from both the orbital motion of an electron around its nucleus and from the intrinsic spin of the electron itself. Carefully choosing and arranging the blocks, one can create an assembly that has zero magnetization and yet still have an overall nonzero electron spin. The existence of a preferred-direction, Lorentz-violating spin-related force would have shown up as a subtle mode in the rotation of the pendulum. The conclusion: any such quasi-magnetic field would have to be weaker than about a femtogauss, or 10^{-15} gauss.

Atom Wires

Physicists have built the world's thinnest gold necklaces, at just one atom wide.

Paul Snijders and Sven Rogge from the Kavli Institute of Nanoscience at the Delft University of Technology, in Delft, Holland, and Hanno Weitering from the University of Tennessee build the single-atom wires by evaporating a puff of gold atoms onto a silicon substrate which has first been cleared of impurities by baking it at 1200 degrees Kelvin. The crystalline surface was cut to form staircase corrugations. Left to themselves, the atoms then self-assemble into wires (aligned along the corrugations) of up to 150 atoms.

Then the researchers lower the probe of a scanning tunneling microscope (STM) over the tiny causeway of gold atoms to study the nano-electricity moving in the chain; the STM both images the atoms and measures the energy states of the atoms' outermost electrons. What they see is the onset of charge density waves– normally variations in the density of electrons along the wire moving in pulselike fashion. But in this case, owing to the curtailed length of the wire, a standing wave pattern is what results as the temperature is lowered.



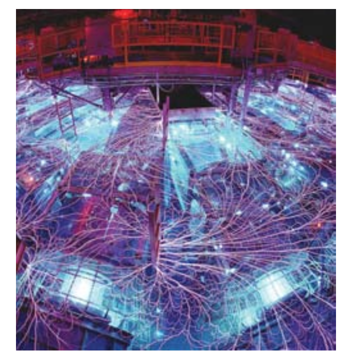
The wave is a quantum thing; hence certain wavelengths are allowed. In other words, the charge density wave is frozen in place, allowing the STM probe to measure the wave–the electron density–at many points along the wire.

Surprisingly, two or more density waves could co-exist along the wire. The charge density disturbance can also be considered as a particle-like thing, including excitations which at times possess a fractional charge. (Snijders et al., *Phys. Rev. Lett*. 96, 076801, 2006)

America's Hottest Lab

A temperature of 2 to 3 billion degrees Kelvin–hotter than the interior of any known star–has been achieved in a lab in New Mexico.

The temperature record was set recently in a test shot at the Z Pinch device at Sandia National Laboratory, where an immense amount of electrical charge is stored in a device called a Marx generator. Many capacitors in parallel are charged up and then suddenly switched into a series configuration, generating a voltage of 8 million volts.



Sandia National Laboratory

This colossal electrical discharge constitutes a current of 20 million amps passing through a cylindrical array of wires, which implodes. The imploding material reaches the record high temperature and also emits a large amount of X-ray energy.

Why the implosion process should be so hot, and why it generates X-rays so efficiently (10 to15 percent of all electrical energy is turned into soft X-rays), has been a mystery.

Now Malcolm Haines of Imperial College, in London, and his colleagues, think they have an explanation. In the hot fireball formed after the jolt of electricity passes through, they believe, the powerful magnetic field sets in motion a myriad of tiny vortices (through instabilities in the plasma), which in turn are damped out by the viscosity of the plasma, which is made of ionized atoms.

In the space of only a few nanoseconds, a great deal of magnetic energy is converted into the thermal energy of the plasma. Last but not least, the hot ions transfer much energy to the relatively cool electrons, energy which is radiated away in the form of X-rays. (Haines et al., *Phys. Rev. Lett*. 96, 075003, 2006)

Rare e-/e+/e- State

The best study of the rare "atom" consisting of two electrons and one positron has been reported.

Positronium (abbreviated Ps) is a very "clean" two-body object: it consists of an electron and a positron which after about 150 nanoseconds annihilate each other. For studying the theory of quantum electrodynamics (QED), Ps is in some ways better even than the hydrogen atom: with pointlike constituents and with no complicating nuclear forces, Ps is a simpler, albeit fragile, quantum system.

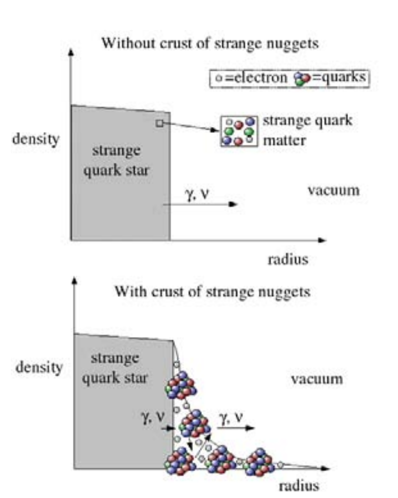
An even more fragile "atom" is the tripartite object consisting of two electrons and one positron. Ps^-, as it is known, is less suitable for QED studies than Ps, but has the great virtue of being the simplest three-body system in physics. Again, it is simpler than H^-, H_2^+, and helium because of its pointlike constituents and the absence of nuclear forces.

Ps^- is, like Ps, a bound state with discrete quantum energy states, although only the ground state is calculated to be stable against dissociation into Ps and a free electron. Very little is known about Ps^- beyond its lifetime.

Now, a new experiment carried out at the Max Planck Institute for Nuclear Physics in Heidelberg has measured the lifetime of Ps^- with a sixfold increase in precision (the new value is half a nanosecond). Ps^- is formed by shooting a positron beam into a thin carbon foil, and its size is actually a bit bigger than a hydrogen atom. (Fleischer et al., *Phys. Rev. Lett*. 96, 063401, 2006)

How Does Matter Terminate?

How does matter terminate? That is, at the microscopic level, how does nature make the transition from a densely packed material surface (the skin of an apple, say) to the nothingness that lies above? This issue is especially dramatic for collapsed stars, where the matter density gradient marking the star-to-vacuum transition can be as great as 10^{26} g/cm^4 (grams per cubic centimeter per centimeter of displacement).



A new model, proposed by physicists at Los Alamos and Argonne National Labs, claims that the prevailing theory of what happens at quark-star surfaces is wrong. These quark stars are characterized by interiors which consist of quark matter from the center all the way to the surface. For quark matter to exist in the low-pressure environment near the surface, matter containing nearly equal numbers of up, down and strange quarks must be preferred over neutrons and protons.

Theorists have speculated about this possibility (often called the Strange Quark Matter Hypothesis) since the early 1980's. A star made in this way, a quark star, is thought to be the densest possible type of matter. Any denser than this, and the star must become a black hole. In the ordinary kind of matter prevailing in our solar system, matter consists of up (u) and down (d) quarks. Converting u or d quarks to strange (s) quarks in neutrons or protons is typically unstable. In the high-density environment of quark stars, however, matter containing up, down, and strange quarks might be stable.

This process really comes into play in collapsed stars, where strange quarks could roughen the surface of the stars. Such a surface, says Los Alamos scientist Andrew Steiner, can be compared to a liquid surface. On Earth, liquid surfaces are generally flat. Because of surface tension, too much energy would be required to overcome the tension and form additional facets above the surface. At a quark star, by contrast, surface tension may not be large and the crust of the star could form extra surfaces, nugget-like objects without any undue energy cost. The positively charged quark lumps would be surrounded by a sea of electrons, as required to make the crust electrically neutral.

What would be the test of the hypothesis of an inhomogeneous termination at a quark-star surface? Again, the Los Alamos group is at odds with the prevailing model, which says that quark stars should be more luminous than neutron stars; this group predicts the quark bumps on an otherwise smooth surface at a quark star would enhance this scattering of photons and neutrinos, lowering the quark star's luminosity. (Jaikumar et al., *Phys. Rev. Lett.* 96, 041101, 2006)

Shock-Produced Coherent Light

Physicists at MIT and Livermore National Lab have discovered a new source of coherent radiation distinct from traditional lasers and free-electron lasers; they propose to build a device in which coherent photons are produced by sending shock waves through a crystal. The result would be coherent light resembling the radiation issuing from a laser; but the mechanism of light production would not be stimulated emission, as it is in a laser, but rather the concerted motion of row after row of atoms in the target crystal.

The passing shock front, set in motion by a projectile or laser blast, successively excites a huge density wave in the crystal; the atoms, returning to their original places in the matrix, emit light coherently, mostly in the Terahertz wavelength band. Although sources of coherent light in this part of the electromagnetic spectrum have developed in recent years, it is still a difficult task.

The next step will be to carry out an experimental test of the shock-wave light production. According to Evan Reed, the first likely application of coherent radiation will be as a diagnostic for understanding shock waves. The radiation should provide information about shock speed and the degree of crystallinity. (Reed et al., *Phys. Rev. Lett.* 96, 013904, 2006)

Nuclear Molecule: Nature's Smallest Dumbbell

An oxygen molecule is a small dumbbell less than a nanometer across: two oxygen atoms with two electrons flying between acting as the bonding agent. Now, an international consortium has succeeded in making a dumbbell far smaller: a beryllium-10 nucleus consisting of two alpha particles with two neutrons flying between acting as a sort of nuclear bonding agency.

This nuclear dumbbell is only a few fermis (10^{-15} m) across. These tiny oblong nuclei are made by colliding a beam of helium-6 nuclei into a gas of helium-4 atoms. (The helium-6 nuclei, which are themselves a novelty, were made by shooting protons at lithium.)

The berillium-10 nuclei created in this way don't live very long. With a lifetime of about 10^{-21} seconds, they fly apart, usually back into helium-4 and helium-6 fragments.

Martin Freer says that the beryllium results support the idea that nuclei sometimes behave like atomic systems in that they can be thought of as a core of particles with extra "valence" particles (electrons/neutrons) exchanged between cores. Several exotic shapes are thought to be possible among the light nuclei. Carbon-12, for instance, can exist as a triangular arrangement of three alpha particles and oxygen-16 as a tetrahedron of alphas. These nuclei are tightly bound, so their exotic geometry cannot be discerned. But berillium-10's prolate shape can be seen clearly through the rotational behavior of the decaying system. (Freer et al., *Phys. Rev. Lett.* 96, 042501, 2006)

Relativistic Electron Cooling

Relativistic electron cooling of an antiproton beam has been demonstrated at Fermilab.

Increasing the density of antiprotons by reducing the spread in longitudinal speeds leads to a larger collision rate in particle colliders, producing more sought-after scattering events that contain rare particles and decays.

Antiprotons, made artificially by smashing protons into a metal target, must be collected on the fly and focused before they can be accelerated and collided with opposite-moving batches of protons; such proton-antiproton smashups are the premier activity at Fermilab's Tevatron facility.

The more compact and tightly focused the two beams are, the more desirable high-energy collisions there will be. The degree of focus and beam density is expressed in a parameter called luminosity. To achieve interesting results it is desirable to have both high collision energy and high luminosity. Taming swarming antiprotons, however, is difficult. One would like all the antiprotons to be co-moving at the same velocity, but because of the way they're made in the first place, they will be flying at high speeds through a beam pipe with a variety of motions, both longitudinal and lateral. The lateral motions can be largely suppressed by a process called stochastic cooling.

Reducing the spread in longitudinal speeds has been harder to accomplish, until now. In the new Fermilab process a continuous beam of electrons at an energy of 4.8 MeV is made to overlap with a beam of 8.9 GeV antiprotons which, because of their higher mass, move at the same speed as the electrons. The electron beam removes some of the unwanted longitudinal velocity spread, increasing thereby the luminosity by a factor of 30 percent. Electron cooling of this kind has been used before but only with much lower-energy particle beams. (Nagaitsev et al., *Phys. Rev. Lett.* 96, 044801, 2006)

Unwired Energy

Recharging your laptop computer or your cell phone might one day be done the same convenient way many people now surf the Web–wirelessly. At the November AIP Industrial Physics Forum, in San Francisco, Marin Soljacic (MIT) spoke about how energy could be transferred wirelessly by the phenomenon of induction, just as coils inside power transformers transmit electric currents to each other without touching. The idea of wireless energy transfer is not new. Nikola Tesla was working on the idea more than a century ago but failed to develop a practical method.

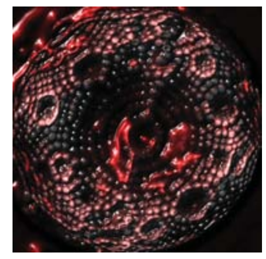
In the new MIT scheme, a power transmitter would fill the space around itself with a non-radiative electromagnetic field–meaning that its energy would not ripple away as electromagnetic waves. Energy would only be picked up by appliances specially designed to resonate with the field; most of the energy not picked up by a receiver would be reabsorbed by the emitter.

Contrary to more traditional, radiative means of energy transmission such as microwaves, it would not require a direct line of sight. It would be innocuous to people exposed to it. With designs proposed by Soljacic in a paper with Aristeidis Karalis and John Joannopoulos, an object the size of a laptop could be recharged within a few meters of the power source. Soljacic and his MIT colleagues are now working on demonstrating the technology in practice.

The Sharpest Object Yet

The sharpest object yet made is a tungsten needle tapering down to about the thickness of single atom.

The needle, made by postdoc Moh'd Rezeq in the group of Robert Wolkow at the University of Alberta and the National Institute for Nanotechnology, starts out much blunter. Exposed to a pure nitrogen atmosphere, however, a rapid slimming begins. To start with the tungsten is chemically very reactive and the nitrogen roughens the tungsten surface. But at the tip, where the electric field created by applying a voltage to the tungsten is at its maximum, N_2 molecules are driven away. This process reaches an equilibrium condition in which the point is very sharp.



Furthermore, what N_2 is present near the tip helps to stabilize the tungsten against further chemical degradation. Indeed, the resultant needle is stable up to temperatures of 900 degrees Celsius even after 24 hours of exposure to air.

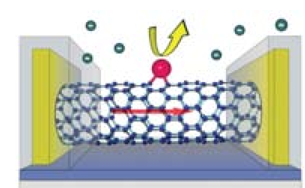
The probe tips used in scanning tunneling microscopes (STMs), even though they produce atomic-resolution pictures of atoms sitting on the top layer of a solid material, are not themselves atomically thin. Rather their radius of curvature at the bottom is typically 10 nm or more.

Wolkow says that although a narrower tip will be useful in the construction of STM arrays (you can pack more tips into a small area; and a wide array might even permit movies of atomic motions) the spatial resolution won't improve thereby. The real benefit of the sharp tungsten tips, he believes, will be as superb electron emitters. Being so slender, they would emit electrons in a bright, narrow, stable stream. (Rezeq, Pitters, and Wolkow, J. *Chem. Phys*. 124, 204716, 2006)

Chemical Transistor

A new device, the chemical equivalent of a transistor, might make possible ultrasensitive bio-medical single-antigen detection.

The things we associate with transistors, the closing or opening of a switch or the amplification of a signal, are normally carried out by injecting a tiny electric signal into a gate electrode which then changes the environment of a nearby channel region. This allows a current to be shut off or to be amplified. In an experiment carried out by physicists at the University of California at Irvine, the same things are done through chemical reactions.



Philip Collins and his colleagues use carbon nanotubes as the central working substance of their device. The nanotubes, immersed in a liquid, can be switched from a conducting state to an insulating state by oxidizing them. The chemical reactions are triggered by an electrical potential applied across the interaction area.

The Irvine researchers showed that this process can be performed reversibly and over short periods of time, as fast as 10 microseconds. This is quite slow by today's transistor standards; the more important promise for prospective chemical field effect transistors (or ChemFETs) is the potentially large amplifications. It looks as if only a few electrons' worth of oxidation can be used to switch currents as large as microamps.

In a future bio-detector the switching would be provided not by an applied electrochemical signal but by the trace presence of antigens docking with antibodies attached to the nanotubes. In previous detectors, chemical actuation has required the presence of tens of antigens; here, a single antigen might be enough to change the state of the nanotube. (Mannik et al., *Phys. Rev. Lett.* 97, 016601, 2006)

Liquid Flowing Uphill; Might Be Used to Cool Chips

In a phenomenon known as the "Leidenfrost effect," water droplets can perform a dance in which they glide in random directions on a cushion of vapor that forms between the droplets and a hot surface. Now, a U.S.-Australia collaboration shows that these droplets can be steered in a selected direction by placing them on a sawtooth-shaped surface.

Heating the surface to temperatures above the boiling point of water creates a cushion of vapor on which the droplet floats. The researchers think that the jagged sawtooth surface, acting as a sort of ratchet, redirects the flow of vapor, creating a force that moves the droplet in a preferred direction. The droplets travel rapidly over distances of up to a meter and can even be made to move up inclines.

This striking method for pumping a liquid occurs for many different liquids (including nitrogen, acetone, methanol, ethanol, and water) over a wide temperature range (from -196 to +151 degrees Celsius). A practical application of this phenomenon might be to cool off hot computer processors. In a concept the researchers plan to test, waste heat in a computer would activate a pump moving a stream of liquid past the processor to cool it off. Such a pump for coolants would need no additional power, have no moving parts, and would spring into action only when needed, when the processor gets warm. (Linke et al., *Phys. Rev. Lett.* 96, 154502, 2006)

Stock Market Criticality

In the months before and after a major stock market crash, price fluctuations follow patterns similar to those seen in natural phenomena such as heartbeats and earthquakes, physicists write in the 17 February *Physical Review Letters.*

A University of Tokyo team studied the Standard & Poor's S&P 500 index, focusing on small deviations from long-term index trends. Such up-and-down blips in stock prices are usually "Gaussian," at least when measured over sufficiently long time scales–for example, for more than one day. That means that fluctuations are likely to be small, while larger fluctuations are less likely, their probabilities following a bell curve.

But when the team looked at 2-month periods surrounding major crashes such as the Black Monday event of October 19, 1987, they saw a different story: Fluctuations of all magnitudes were equally probable. As a consequence, the graph of index fluctuations looked statistically similar if plotted over different time scales, anywhere between time scales of 4 minutes and two weeks.

Such behavior is called critical in analogy with a ferromagnetic metal at the "critical temperature," when regions form where the metal's atoms arrange their spins in the same direction, and these regions look similar at different levels of magnification. This self-similarity is also seen in the time intervals between heartbeats, or between earthquakes. Mathematically, however, the stock market case differs in that the probabilities do not change with the size of the event, while in other cases of non-critical self-similarity, the probabilities usually follow a power law.

It is unclear what individual trading decisions lead to criticality in the stock market, co-author Zbigniew Struzik says, although he and the team at the University of Tokyo are working on finding explanations. Also unclear is whether the findings could one day lead to an early-warning system to predict crashes, and if such a system would precipitate a crash– or create one artificially–by inducing panic. (Kiyono et al., *Phys. Rev. Lett.* 96, 068701, 2006)

ANNOUNCEMENTS

H. Frederick Dylla Succeeds Marc Brodsky as Head of the American Institute of Physics

H. Frederick Dylla has been selected to be the next Executive Director and CEO of the American Institute of Physics. AIP is an organization made up of ten member societies, including APS.

Dylla will start working at AIP on March 1, 2007. He will replace Marc H. Brodsky, who will retire on March 31 after more than 13 years at AIP's helm. Dylla will assume the role of CEO and Executive Director on the following day, April 1, 2007.


Photo courtesy of AIP
H. Frederick Dylla

"Fred has already been an invaluable member of the AIP family," says AIP Governing Board Chair Mildred Dresselhaus. "His ideas and initiatives have enhanced AIP and its Member Societies for many years. As the next CEO and Executive Director, his experience, enthusiasm, and outward-looking nature will drive AIP in the right direction as we work with the rest of the scientific community to confront a future filled with challenges."

"Having interacted with Fred over many years," says APS Executive Officer Judy Franz, "I can attest to his ability and judgment. I look forward to working closely with him in his new position,"

"I'm honored to be selected to be the next AIP Executive Director," says Dylla. "I am very optimistic for the outlook of the Institute to continue to grow in its role of supporting the value of physics for its Member Societies, the physics community and the world at large. I look forward to working with the Member Societies to continue to provide first-rate services and to collaborate on joint activities."

Dylla has been with the U.S. Department of Energy's Thomas Jefferson National Accelerator Facility (Jefferson Lab) in Newport News, Virginia since 1990. During this time, he has concurrently held an Adjunct Professorship in Physics and Applied Science at the College of William and Mary. He received his B.S., M.S. and PhD in physics from the Massachusetts Institute of Technology.

Holding a career-long interest in science education, Dylla helped to found the K-12 science education programs at Jefferson Lab. He founded similar programs at Princeton University's Plasma Physics Laboratory, where he held various research and management positions from 1975 to 1990. While at Princeton, he helped develop technology for nuclear fusion reactors, particle accelerators, and materials processing.

At Jefferson Lab, Dylla served as the Chief Technology Officer and Associate Director for the Free-Electron Laser (FEL) program. Dylla served on the AIP's Governing Board in the early 1990s and rejoined the Board in 2004. He is a Fellow of the American Physical Society. He is a founding member of the Forum of Industrial and Applied Physics, currently the largest unit of the APS.

Outgoing CEO and Executive Director Marc Brodsky will have served AIP for thirteen and a half years when he retires at the end of March 2007. "I am pleased that AIP will be in such good hands," says Brodsky. "Fred brings valuable managerial experience to AIP and his stature in the physics community instills confidence that AIP will continue to serve its broad constituencies well."

During his tenure, Brodsky oversaw dramatic changes in AIP publishing and publishing services, as nearly all editorial, production, distribution and business processes were changed to deal with electronic publishing. All the journals and magazines AIP publishes for itself and others went onto the World Wide Web, increasing access to the physics literature to more people than ever before in history. AIP outreach programs and services expanded its informational offerings for the general public to the Web and many other media outlets, including regular science news segments to over 50 million nightly viewers of local TV news programs. He also actively defended AIP's freedom of the press rights on many fronts, including attempted government restrictions on the processing of manuscripts from certain countries and suits from some who tried to restrict knowledge gained from comparisons of journal prices.

American Institute of Physics Prize for Industrial Applications of Physics 2007-2008

Awarded on behalf of the Corporate Associates of the American Institute of Physics

Sponsored by the General Motors Corporation and AIP Corporate Associates

PURPOSE

To recognize outstanding contributions by an individual or individuals to the industrial applications of physics.

THE AWARD

The prize consists of $10,000, an allowance for travel to receive the prize, and a certificate citing the contributions made by the recipient(s).

For more information see:
www.aip.org/ca/iaprize.html

Nominations must be postmarked by May 1, 2007.

Now Appearing in RMP: Recently Posted Reviews and Colloquia

You will find the following in the online edition of *Reviews of Modern Physics* at http://rmp.aps.org

Atomic data for x-ray astrophysics
T.R. Kallman and P. Palmeri

The field of x-ray astrophysics has evolved rapidly in recent years. This has been driven by advances both in observational data of high statistical quality and spectral resolution from x-ray astronomy satellites and in the understanding of the astrophysical implications of x-ray spectra associated with planets, comets, and other primarily neutral or solid objects. This review covers extensively as well atomic data from cosmic sources driven by electron ionization and photoionization as their applications to x-ray astronomy.

Conference on Communicating Science to a Broader Audience

April 12-13 2007
University of Nebraska, Lincoln

Plenary Speakers: Curt Suplee (NSF); Sidney Perkowitz (Emory University)

Panelist Include: David Ehrenstein (PR Focus); Sean Carroll (Caltech); Jennifer Ouellette (author and editor); Tim Gay (University of Nebraska)

Registration Deadline: March 1, 2007

For the full program and more information: http://physics-new.unl.edu/~diandra/communicatingscience/

CORRECTION

The image of a wakefield on page 6 of the December *APS News* in an article about the 2006 Division of Plasma Physics meeting appeared without attribution. The wakefield imaging was done by a collaboration between the University of Texas at Austin and the University of Michigan, and was the subject of a tutorial session at the meeting. We thank Michael Downer of the University of Texas for pointing out our omission.

PHYSICIST continued from page 3

straight on the river. Binger estimates the odds of it happening twice in a row at 70 to 1. Still, he was philosophical about the loss, figuring he'd gotten his bad luck out of the way.

Not that he's superstitious, mind you: "Your runs of luck will generally not be out of bounds with what the probability statistics say," he insists. According to Binger, luck only reigns in the short term. Over the long term, the percentages hold sway. He keeps careful records of his own wins and losses, and insists he's never had a losing year as a poker player. In fact, he has earned the majority of his income since 2002 from poker.

Binger's strong showing at the WSOP gives him a healthy bankroll to play a few more big tournaments, but he hasn't given up on physics entirely. He still has an office at SLAC, and eventually hopes to find a balance between physics research and poker. Ideally, he would like to do well enough at amassing poker winnings to conduct his theoretical research without having to scrounge for grant money. Then again, he could write his own book on poker strategy, or perhaps follow in the footsteps of poker champion Phil Gordon by hosting Celebrity Poker Showdown. His future could quite literally be in the cards.

INTERNATIONAL NEWS continued from page 3

gram, and scientific communities outside of the fusion community, because it is applicable to large-scale scientific collaboration in general. Clearly, the ITER Agreement starts out with a purpose statement specifically directed at ITER, but virtually every other provision deals with How the Parties will interact with each other and the Director General as the project evolves. The ITER Agreement addresses issues such as governance, resources, and intellectual property rights, rather than plasma confinement, heating and diagnostics. These negotiations, recently formally concluded, involved the technical (Energy for US) and foreign (State for US) ministries of each of the Parties, including specialists from many sectors. As a participant in these negotiations, privy to the many individual discussions and considerable time and human resources required that led to consensus on a myriad of difficult points, I believe it highly unlikely that any person or Party would seriously entertain trying to redo these compromises for the next large project. Therefore, I believe that the ITER Agreement, once signed and entered into force, should be a most useful document with lasting value as it will represent a significant body of governmental agreements on how to work together. This would then be available for use with only minor changes for future large-scale international scientific collaboration. I appreciate the opportunities given to me by my former employers, ORNL and DOE, and all my colleagues, at home and abroad, to participate in and contribute to these unparalleled experiments in international collaboration and welcome the next generations of researchers to build on these foundations of hard-won trust, continuity of service, and crucial support at highest political levels around the world.

Michael Roberts, recently retired from the Office of Fusion Energy Sciences, within the DOE Office of Science, was responsible for US international fusion programs from February 1979 through April 2006; he joined the ORNL Fusion program in 1966. He has served as Chair of the IEA Fusion Power Coordinating Committee and as Chair of the ITER Contact Persons. The views in this note are his alone and do not purport to represent those of the US DOE.

The Back Page

Editor's Note: APS recently instituted an open acccess initiative for its journals called "Free to Read"(see the October 2006 APS News*, available online). Open Access is a controversial idea, and much of the impetus for it has come from within the biomedical community. This article surveys the issue from the perspective of a molecular biologist.*

The Future of Science is Open (Access)

By Bill Hooker

I've never had an idea that couldn't be improved by sharing it with as many people as possible–and I don't think anyone else has, either. That's why I have become interested in the various "open" movements making increasing inroads into the practice of modern science. The best known of these, apart from the familiar Open Source (Free) Software movement, is the Open Access approach to research literature.

Open Access (OA) entails the freedom to read, use and redistribute the published results of scholarly research and derivative works based on those publications. OA literature is digital, online, free of charge and free of most licensing restrictions. What makes it possible is the consent of the author or copyright-holder (hence the focus on scholarly articles, for which authors are not usually paid), and the internet. Online publishing is much less expensive than its print-only ancestor, but it is not free; the big question of OA is how to pay the bills that do remain without charging access fees. Nearly all current OA models reduce to one of two basic blueprints: OA archives/repositories, and OA journals.

OA archives or repositories simply make their contents freely available to the world. They may contain preprints, refereed postprints, or both. Archiving preprints does not require any form of permission, and a majority of journals already permit authors to archive their postprints. Archives which comply with the metadata harvesting protocol of the Open Archives Initiative are interoperative and can be searched as though they comprised a single virtual database, using services such as OAIster. There are a number of open-source software packages available for building and maintaining OAI-compliant archives; Peter Suber maintains a list of lists of such archives, and SHERPA maintains a database of journal policies regarding pre/post-print archiving. Archives cost very little to set up and maintain, and increasing numbers of universities and research institutions are building their own. PubMed Central, maintained by the NIH, is probably the largest and best-known in biomedical science. ArXiv, run by Cornell University, is the principal means of transfer of research results for many (if not most) mathematicians and physicists.

OA journals are in most respects the same sorts of entities as traditional paid-access journals, but without the access fees. They perform peer review, and make the refereed articles available free to all comers. They pay the bills in a number of different ways. About half charge author-side fees, though who actually pays these is widely variable (author, author's institution, funding body, etc.). The Directory of Open Access Journals (www.doaj.org) currently lists nearly 2500 peer-reviewed OA journals. Three of the most prominent OA journal publishers are the Public Library of Science, Hindawi Publishing and BioMed Central, and a number of traditional publishing companies now offer OA options.

A Personal Example. More than half of my publications to date are not freely available from the journals in which they were published. You cannot read them without paying a fee or relying on a library which carries (and has therefore paid for) the journal and issue in question, and neither can my professional colleagues.

For you as a taxpayer, this means that you are denied access to information for whose production you've already paid (since I've always been funded by government grants). For me as a scientist, it means that more than half of my work is, while not useless, certainly of much less use to the world than it might be. Fortunately, all of the journals concerned allow postprint archiving (though they don't allow use of the published pdf), so I might be able to rescue it. I'll have to either find a repository that will take the articles, or make one of my own. Whatever I do, I'm going to have to track down the published versions and then reverse-engineer an "unofficial" version. Why would I go to all this trouble? Because OA offers significant benefits and advantages to a variety of stakeholders:

Maximal research efficiency. The usual version of Linus' Law says that given enough eyeballs, all bugs are shallow–meaning that with enough people co-operating on a development process, nearly every problem will be rapidly discovered and solved. The same is clearly true of complex research problems, and OA provides a powerful framework for co-operation. For instance, Brody et al. showed that, for articles in the high-energy physics section of arXiv, the time between deposit and citation has been decreasing steadily since 1991, and dropped by about half between 1999 and 2003. Alma Swan explains: "the research cycle in high energy physics is approaching maximum efficiency as a result of the early and free availability of articles that scientists in the field can use and build upon rapidly."

Moreover, the machine readability of a properly formatted body of open access literature opens up immense new possibilities. Paul Ginsparg, founder of arXiv, observes:

True open access permits any third party to aggregate and data mine the articles, themselves treated as computable objects, linkable and interoperable with associated databases. We are still just scratching the surface of what can be done with large and comprehensive full-text aggregations.

Examples include cheminformatics.org and the family of utilities and tools available through the NIH/NLM's PubMed interface.

Maximal return on public investment. Just as OA is primarily aimed at literature for which the authors are not paid royalties, so one obvious focus of attention is government-funded research. Why should taxpayers pay twice, once to support the research and then again when the scientists they are funding need access to the literature? Open access to a body of knowledge makes that knowledge more available and useful to researchers, physicians, manufacturers, inventors and others who make of it the various socially desirable outcomes, such as advances in health care, that government funding of research is intended to produce.

Advantages for authors. There are well over 20,000 scholarly journals, and even the best-funded libraries can afford subscriptions to only a fraction of them. OA offers authors a virtually unlimited, worldwide audience: the only barrier is internet access. There is a large and steadily growing body of evidence showing that OA measurably increases citation indices. For instance, of the papers published in the *Astrophysical Journal* in 2003, 75% are also available in the OA arXiv database; the latter papers account for 90% of the citations to any 2003 *Astrophysical Journal* article, a 250% citation advantage for OA. Repeating the exercise with other journals returns similar results.

Not only is this of vital importance to academics when it comes to applying for funding or competing for tenure, it's more or less the whole point of publishing research in the first place: so that other people can read and use it.

Advantages for publishers: the benefits that accrue to authors of OA works also work to the advantage of publishers: more widely read, used and cited articles translates to more submissions and a wider audience for advertising, paid editorials and other value-add schemes.

Advantages for administrators. One of the best available proxy measures for research impact is citation counting: how many times has a given paper been cited by other researchers in their published work? This idea led to the development of the impact factor, a measure of a particular journal's importance within its own field. These sorts of bibliometric indicators are relied upon heavily by science administrators making decisions about funding, tenure, and so on. Open access, by removing the subscription barriers that splinter the research literature into inaccessible proprietary islands, raises the possibility of vast improvements in our ability to measure and manage scientific productivity.

Scalability. Peter Suber has pointed out that, because it reduces production, distribution, storage and access costs so dramatically, OA "accommodates growth on a gigantic scale and [...] supports more effective tools for searching, sorting, indexing, filtering, mining, and alerting–the tools for coping with information overload." Online distribution is necessary but not sufficient for scalability, because subscribers to paid-access journals do not have unlimited budgets. For end users to keep pace with the explosive growth of available information, the cost of access has to be kept down to the cost of getting online.

Open Science. There is growing interest in extending the "open" aspect of Open Access to science as a whole. In a 2003 essay, Stephen Maurer noted that:

Open science is variously defined, but tends to connote (a) full, frank, and timely publication of results, (b) absence of intellectual property restrictions, and (c) radically increased pre- and post-publication transparency of data, activities, and deliberations within research groups.

Peter Murray-Rust recently put together a Wikipedia page on Open Data:

He writes: "Open Data is a philosophy and practice requiring that certain data are freely available to everyone, without restrictions from copyright, patents or other mechanisms of control."

There are (I think) at least two requirements beyond Access and Data: Open Standards, and Open Licensing. Consider the following citation:

Hooker CW, Harrich D. The first strand transfer reaction of HIV-1 reverse transcription is more efficient in infected cells than in cell-free natural endogenous reverse transcription reactions. *Journal of Clinical Virology* vol 26 pp.229-38 (2003)

You can read that, but a computer cannot do anything really useful with the text string as given: it has no idea which part of the string means me and which means my co-author, where the title begins and ends, which numbers are page numbers and which are a date, and so on. Now remember that PubMed, the database from which I got it, contains millions of such citations (and abstracts, and links between papers that cite each other, and so on). Stored as text strings, they would be impossibly clumsy, but see what happens with the addition of simple metadata (in bold):

***Author/s**: Hooker CW, Harrich D.* ***Title**: The first strand transfer reaction of HIV-1 reverse transcription is more efficient in infected cells than in cell-free natural endogenous reverse transcription reactions.* ***Journal**:* Journal of Clinical Virology ***Volume**: 26* ***Pages**: 229-238* ***Year**: 2003.*

Now the citation is broken down into meaningful fields, each of which can be manipulated separately. The computer can now treat each string after "Author/s:" as a series of comma-delimited substrings (author names), the numbers after "Pages:" as a numerical range, and so on–which means you can ask the database useful questions, like "show me all the papers written by Hooker, CW between the years 2000 and 2006 and published in J Virol." There you have a very simple example of the two pillars of a semantic web: metadata and standards.

Semantic markup is going to be increasingly necessary to scientific communication and analysis as more and more of it takes place online and as datasets grow ever larger and more complex. Science Commons makes the point using the tumor suppressor TP53:

There are 39,136 papers in PubMed on P53. There are almost 9,000 gene sequences [...] 3,800 protein sequences [and] 68,000 data sets available. This is just too much for any one human brain to comprehend.

Quite apart from lack of brainspace, there are answers in those datasets to questions that their creators never thought to ask. In the same way that Open Access accelerates the research cycle and facilitates collaboration, so too does Open Data–and Open Standards is the infrastructure that makes it possible.

Similarly, Open Licensing also provides a kind of infrastructure–in this case, for dealing with intellectual property issues. It's fine to simply put your product on the web and let the world do as it will, but many people prefer to retain some control over what others do with their work. In particular, if you are concerned with openness you may want to ensure that the original and all derivative works remain part of the commons. That means reserving at least some rights, which is where licensing comes in. Open copyright licenses are fairly well established, from software licenses like the GPL to the various Creative Commons deeds. In contrast, efforts to make patent-based licenses "open" are just beginning. Science Commons is working on materials transfer agreements, and PIPRA and CAMBIA offer two working models for technology and data licensing.

Overall, I think "Open Science" is the banner under which the various Open X clans might most profitably assemble. Access and Data are crucial by definition, and although you could do Open Science on proprietary software (provided you made data and publications openly accessible), it is much more efficient to use Open Source software that is available to everyone without intellectual property or cost barriers. Similarly, Open Standards and Open Licensing might not be fundamental to the practice of Open Science, but both make possible such vast increases in efficiency that I would argue for their inclusion in any comprehensive definition or declaration.

In short, Open (Access + Data + Source + Standards + Licensing) = Open Science.

Bill Hooker is a molecular biologist by trade; he lives in Portland, OR and works on Myc-related transcription factors in cancer and development.

Further Reading:

- http://www.earlham.edu/%7Epeters/fos/overview.htm
- http://3quarksdaily.blogs.com/3quarksdaily/2006/10/the_future_of_s_1.html
- http://3quarksdaily.blogs.com/3quarksdaily/2006/11/the_future_of_s.html

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