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Physics News in 2005
Inside this issue

DOE Picks University of California to Head Los Alamos Management Team

The Department of Energy announced in December its decision to award the contract to manage Los Alamos National Laboratory to Los Alamos National Security, LLC. (LANS), a partnership led by the University of California, partnered with Bechtel Corporation, a huge engineering, construction and project management company.

The University of California has run Los Alamos National Lab since the lab was created in 1943. But a series of safety, security, and financial problems in the past two years cast doubt on the university's ability to manage the lab, and the DOE decided to put the contract out for a competitive bid.

Some at Los Alamos believe the problems have been blown out of proportion, and the contract didn't need to be rebid. Other major labs have similar levels of safety and security, said Brad Holian, a Los Alamos physicist. "It's not that Los Alamos is singularly bad. It seems to me is it was a drive to privatize. I think it's a very bad idea."

The LANS partnership that will take over the management of the lab includes the University of California, Bechtel Corporation, BWX Technologies, and Washington Group International. They were competing for the contract against a team led by Lockheed Martin and the University of Texas.

"Both proposals were strong and of exceptionally high caliber," said Energy Secretary Samuel Bodman at a press conference in December announcing the decision to award the contract to the UC/Bechtel team.

Bodman stressed that the new contract would not be a continuation of the previous contract. "This is a new contract, with a new team, marking a new approach to management at Los Alamos."

That new approach includes a new attitude towards monetary compensation. The new contract, which begins June 1, has an initial term of seven years, with a provision to extend it to 20 years. Under the new contract, the LANS team will receive up to $79 million per year, depending on performance. Previously, the University of California had received about $9 million per year to manage the lab.

The new contract "begins a new era for Los Alamos," University of California President Robert Dynes said in a statement after the announcement. "I believe this was an excellent decision and one that is right for both Los Alamos and the country."

Details on how operations at the lab will change under the new management have not been announced.

"This new contract will put in place concrete measures of accountability, ensuring that the tax dollars spent at Los Alamos are well spent," said Bodman.

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Use the New APS Logo

For camera ready versions of the logo visit http://www.aps.org/logo.cfm

Sorting, sorting...

Photo credit: Ernie Tretkoff

The 2006 March Meeting received more than 6500 abstracts, and sorting them all into sessions is a highly non-trivial task. Undaunted, a dedicated group of volunteers, part of which is pictured here, gathered at APS headquarters in College Park on December 9 and 10 for this purpose. As the picture shows, a great time was had by all.

De Gennes, Ben Lakhdar and Wagner to Deliver Endowed Lectures at March and April Meetings

This year two named APS lectureships will bring distinguished foreign scientists to speak at the March and April meetings. The speakers were selected by the APS Committee on International Scientific Affairs (CISA), from nominations submitted by various APS units.

The Beller Lectureship was endowed by Esther Hoffman Beller for the purpose of bringing distinguished physicists from abroad as invited speakers at APS meetings. The lectureship provides support for speakers at the March and April meetings.

The Marshak Lectureship, endowed by Ruth Marshak in honor of her late husband and former APS president, Robert Marshak, provides travel support for physicists from a developing country or Eastern Europe invited to speak at APS meetings.

The March Beller lecture will be given by Pierre-Gilles de Gennes, of the Collège de France. De Gennes is a leading exponent of soft condensed matter physics. He received the 1991 Nobel Prize in Physics for his generalization of physical order descriptors to complex soft matter. At the March Meeting, de Gennes will present a talk on "The Nature of Memory Objects in the Brain." De Gennes was nominated for the Beller Lectureship by the Division of Polymer Physics.

The 2006 Marshak lecturer will be Zohra Ben Lakhdar of the University of Tunis. She will give a talk at the March Meeting entitled "Scientists in Developing Countries: Is there an effective way to support meaningful research?" Ben Lakhdar's research focuses on atomic spectroscopy, and she is devoting her career to carrying out applied research to meet national needs in Tunisia. She is the recipient of the 2005 UNESCO–L'Oréal prize for Women in Sciences for her experiments and models on infrared spectroscopy and its applications to pollution, detection and medicine. Ben Lakhdar was nominated for the Marshak lectureship by the Forum on International Physics.

At the April Meeting, the Beller Lecture will be given by Albrecht Wagner, director of DESY, the German particle physics laboratory. Wagner has been a leading proponent of the

Endowed Lectures continued on page 11

Taiwan Symposium Caps WYP Talent Search Program

As a closing event for the World Year of Physics, students from about 20 different countries attended a special "Physics Young Ambassadors" symposium in Taipei from December 31, 2005 to January 4, 2006. These students, ages 10-18, were chosen to attend the event through an international program, the WYP 2005 Talent Search.

The International Coordinating Committee for the Talent Search was chaired by Beverly Hartline of Heritage University. The NSF provided travel grants for the Young Ambassadors from the United States, and also for those from Argentina, Cameroon, Ghana, Indonesia, and Tanzania, to the symposium in Taipei. The American Association of Physics Teachers helped coordinate travel for these groups.

At the international symposium, students attended a wide variety of events, including presentations by distinguished physicists, a "physics is fun" session with hands-on activities, a poster session for the students to present their work, a

Taiwan Symposium continued on page 3

APS Commemorates Compton

Photo credit: Mary Butkus

On December 12, then APS President-elect (now APS President) John Hopfield presented a plaque in honor of Arthur H. Compton at Washington University in St. Louis. This was the third plaque to be presented as part of the ongoing APS historic sites initiative; the first two honored Benjamin Franklin in Philadelphia, and Michelson and Morley at Case Western Reserve University in Cleveland. Compton was a professor at Washington University, studying the scattering of X-rays, when he discovered the effect named after him in 1922. As part of the presentation ceremony, Hopfield signed the APS Ledger of Historic Sites. Watching as he signs the Ledger are John Rigden (center), Chairman, APS Historic Sites Committee, and Mark S. Wrighton, Chancellor, Washington University in St. Louis.

Optical Illusion

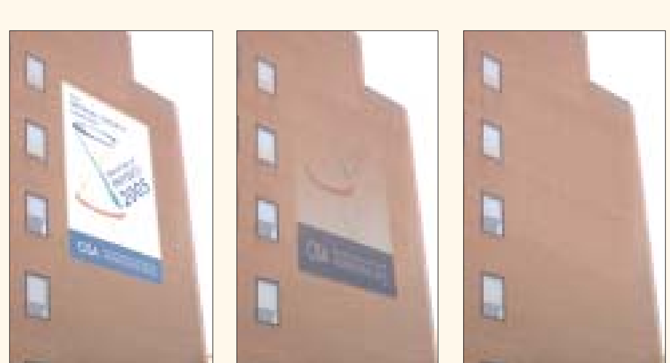


Photo credit: Gary Stoiber

For most of 2005, a giant banner with the World Year of Physics logo hung down the side of the building housing the Optical Society of America in Washington, DC. It became a familiar sight to commuters as they exited the Dupont Circle Metro station. But nothing lasts forever, and as the World Year of Physics faded into memory (see Viewpoint on page 4) so too did the OSA banner.

Members in the Media

"People on the Earth are not moving at the same speed as the atomic clocks on the satellites."

–Brett Taylor, Radford University, on why GPS systems would not work without factoring in relativity, Roanoke Times, December 28, 2005

"The discovery also explains why this black hole is so bright in X-rays. It's because the black hole can pull gas directly off from the outer layers of the giant star."

–Philip Kaaret, University of Iowa, on the discovery of a giant star orbiting a medium sized black hole, Associated Press, January 8, 2006

"It is very unpleasant to have a 5,000-pound instrument crash into your living room."

–Scott Nutter, Northern Kentucky University, on why the cosmic ray detector instruments had to be flown on balloons over an uninhabited area, Cincinnati Enquirer, January 11, 2006

"Once you go down that road it is very difficult to make a U-turn and go back to where you were,"

–Mike Lubell, APS and CUNY, on budget cuts that will cause lay-offs and cutbacks at RHIC, Associated Press, January 2, 2006

"Black hole processes are perhaps the most exciting source of gravitational waves. Don't you think that a region of the universe from which no escape is possible, even in principle, is exciting?"

–Richard Price, University of Texas at Brownsville, on gravitational waves and black holes, The Brownsville Herald, December 14, 2005

"We can now go inside a [cell] structure and see how it feels. We are able to interact with the nanoworld."

–Gustavo Luengo, L'Oréal, on powerful microscopes and probes that allow him to view and poke individual atoms, Business Week, December 12, 2005

"I would argue that intelligent design is not science. When faced with an organism, they say it's too complex to have appeared from evolution. So they invoke divine intervention, and then they stop thinking. That's what intelligent design is. It's lazy thinking."

–Rush Holt, US House of Representatives, Trenton Times, December 22, 2005

"As a scientist, I'd think sometimes it's good to have a little controversy to be sure what's being taught."

–Robert Kaita, Princeton Plasma Physics Laboratory, supporting intelligent design, Trenton Times December 22, 2005

Members in the Media contiued on page 4

INSIDE THE BELTWAY: WASHINGTON ANALYSIS AND OPINION

Don't Give Me No Bad News!

By Michael S. Lubell, APS Director of Public Affairs

You don't have to be a soldier in Iraq to know that the world is filled with mines. And not all of them are improvised explosive devices, concealed and instantly lethal. No, the ones I have in mind are visible, and they pack a delayed charge, one that can cripple America the mighty.

You have to have your eyes shut, your ears plugged or your entire head in the sand not to know they're there. But that's just about how the White House has behaved for the last five years when it comes to the high tech challenges our country is facing from abroad.

Call it arrogance or ignorance, but, until recently, the West Wingers just didn't get the idea that "Science and Technology" is not an American protectorate. They've been so focused on their rosy optimism they haven't seen the mines ahead or the enemies behind. For them, "It's morning in America!" is more than a Reagan campaign slogan–it's the reality. Would that it were true.

Yes, we lead the world in entrepreneurs and venture capitalists. We have the strongest banking system, the best protection of intellectual property rights and the greatest graduate institutions. But we also have one of the poorest performance records in elementary and

Inside the Beltway continued on page 11

This Month in Physics History

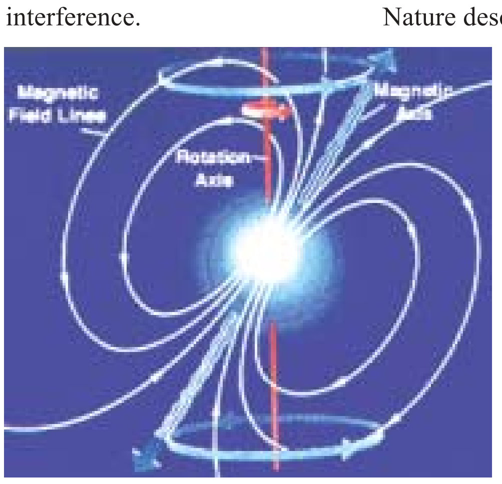
February 1968: The Discovery of Pulsars Announced

In 1967, when Jocelyn Bell, then a graduate student in astronomy, noticed a strange "bit of scruff" in the data coming from her radio telescope, she and her advisor Anthony Hewish initially thought they might have detected a signal from an extraterrestrial civilization. It turned out not be aliens, but it was still quite exciting: they had discovered the first pulsar. They announced their discovery in February 1968.

Bell, who was born in Ireland in 1943, was inspired by her high school physics teacher to study science, and went to Cambridge to pursue her PhD in astronomy. Bell's project, with advisor Anthony Hewish, involved using a new technique, interplanetary scintillation, to observe quasars. Because quasars scintillate more than other objects, Hewish thought the technique would be a good way to study them, and he designed a radio telescope to do so.

Working at the Mullard Radio Astronomy Observatory, near Cambridge, starting in 1965 Bell spent about two years building the new telescope, with the help of several other students. Together they hammered over 1000 posts, strung over 2000 dipole antennas between them, and connected it all up with 120 miles of wire and cable. The finished telescope covered an area of about four and a half acres.

They started operating the telescope in July 1967, while construction was still going on. Bell had responsibility for operating the telescope and analyzing the data–nearly 100 feet of paper every day–by hand. She soon learned to recognize scintillating sources and interference.



Artist's rendering of a pulsar

Jocelyn Bell ca. 1970

Within a few weeks Bell noticed something odd in the data, what she called a bit of "scruff." The signal didn't look quite like a scintillating source or like manmade interference. She soon realized it was a regular signal, consistently coming from the same patch of sky.

No known natural sources would produce such a signal. Bell and Hewish began to rule out various sources of human interference, including other radio astronomers, radar reflected off the moon, television signals, orbiting satellites, and even possible effects from a large corrugated metal building near the telescope. None of those could explain the strange signal.

The signal, a series of sharp pulses that came every 1.3 seconds, seemed too fast to be coming from anything like a star. Bell and Hewish jokingly called the new source LGM-1, for "Little Green Men." (It was later renamed.)

But soon they managed to rule out extraterrestrial life as the source of the signal, when Bell noticed another similar signal, this time a series of pulses arriving 1.2 seconds apart, coming from an entirely different area of the sky. It seemed quite unlikely that two separate groups of aliens were trying to communicate with them at the same time, from completely different locations. Over Christmas 1967, Bell noticed two more such bits of scruff, bringing the total to four.

By the end of January, Bell and Hewish submitted a paper to Nature describing the first pulsar. In February, a few days before the paper was published, Hewish gave a seminar in Cambridge to announce the discovery, though they still had not determined the nature of the source.

The announcement caused quite a stir. The press jumped on the story–the possible finding of extraterrestrial life was too hard to resist. They became even more excited when they learned that a woman was involved in the discovery. Bell later recalled the media attention in a speech about the discovery: "I had my photograph taken standing on a bank, sitting on a bank, standing on a bank examining bogus records, sitting on a bank examining bogus records. Meanwhile the journalists were asking relevant questions like was I taller than or not quite as tall as Princess Margaret, and how many boyfriends did I have at a time?"

Other astronomers were also energized by the finding, and joined in a race to discover more pulsars and to figure out what these strange signals were. By the end of 1968, dozens of pulsars had been detected. Soon Thomas Gold showed that pulsars are actually rapidly rotating neutron stars. Neutron stars were predicted in 1933, but not detected until the discovery of pulsars. These extremely dense stars, which form from the collapsed remnants of massive stars after a supernova, have strong magnetic fields that are not aligned with the star's rotation axis. The strong field and rapid rotation produces a beam of radiation that sweeps around as the star spins. On Earth, we see this as a series of pulses as the neutron star rotates, like a beam of light from a lighthouse.

After discovering the first pulsars, Jocelyn Bell finished her analysis of radio sources, completed her PhD, got married and changed her name to Burnell. She left radio astronomy for gamma ray astronomy and then x-ray astronomy, though her career was hindered by her husband's frequent moves and her decision to work part time while raising her son. Anthony Hewish won the Nobel Prize in 1974 for the discovery of the first pulsars. Over 1000 pulsars are now known.

As for little green men, they haven't been found yet, but projects such as the Search for Extra Terrestrial Intelligence (SETI) are still looking for them.

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INDUSTRIAL PROFILE

By Ernie Tretkoff

Ed. Note: With this article we inaugurate an occasional series of profiles of physicists with careers in industry.

Over his long and successful career as an industrial physicist, Charlie Duke has watched industry change dramatically and now sees industry moving into a new era in which the United States must struggle to keep up in a global economy.

Duke originally went into physics somewhat by chance. He started out in college in 1955 at Duke University as a religion major, intending to become a minister. After his junior year he realized it wasn't for him. He switched his major to mathematics, but his roommate happened to be a physics major, so Duke took some graduate level physics courses, and found he excelled in them. Professors pushed him to go on to graduate school, and he did.

After completing his PhD at Princeton University in 1963, Duke found that physicists were very much in demand in industrial labs. "Sputnik had happened, and everyone was recruiting physicists," he recalls. "I was in demand, to my utter shock."

Duke started his career in industry as a staff researcher at General Electric in 1963. From 1969 to 1972 he was a professor of physics at the University of Illinois. He joined Xerox Corporation in 1972 as a scientist in the materials research section, and has been at Xerox in various positions since then.

Even though a career in physics wasn't his original plan, Duke has been extremely successful. He has been elected to the National Academy of Sciences and the National Academy of Engineering, has won several prestigious prizes, including most recently the 2006 APS George E. Pake Prize. "That just goes to show that if you are determined and persistent you can do something." he says.

When he started at Xerox in 1972, Duke's research focused on the electronic structure of molecular solids. Models he developed helped enable Xerox to produce flexible organic photoconducting belts that could be wrapped around small rollers to enable high speed photocopying with small machines. The polymer belts helped create billions of dollars in revenue and helped the Xerox company to survive after it was forced to allow other companies to use its patents in 1975.

"Organic photoconductors turned out to be the essential innovation that allowed the company to survive," he says. "Applying the physics of how charges go through polymers was one of many things that made it possible. The research was a vital part of the third generation of xerographic technology."

Duke has also conducted research on other topics, including electron tunneling, semiconductor surface structure, tunneling in solids, and inelastic scattering of low-energy electrons in solids.

Duke drifted into a variety of research and management positions, simply by taking charge and doing what needed to be done. He has managed research groups of various sizes and has recently retired as Vice President and Senior Research Fellow of Xerox Innovation Group.

Having worked in both industry and academia, Duke has noticed quite a difference between the two environments. "The successful person at a university is an independent businessman. You get your grant, and you run your show. You're like a small businessman. No one tells you what to do or how to do it. It's every man for himself."

Industry is the opposite extreme, says Duke. "When a young person comes to work for Xerox, they are put into a project. They are told what to do. They work on a schedule. Their resources are largely beyond their control."

The social environments are very different, as well, he says. At a university, people socialize with others in their department. But not in industry. "There is very little social life at Xerox. It's a very hierarchical structure. If you're a boss, you have power over people. So it's not appropriate to socialize too much. It's intensely competitive," says Duke, "That was one of my biggest shocks."

In industry, the focus is always on producing a valuable product for the customer, unlike in the university, where research can be largely curiosity-driven. Duke clearly thinks in terms of economic value all the time. Giving customers products they value is the most important consideration. "If you don't get the product out, then the company doesn't survive, so there is a lot more intensity at an industrial organization."

Over the course of his career, Duke has seen major changes in industry. Between the end of World War II and the end of the Cold War, large companies owned enormous industrial research laboratories, such as ATT's Bell Labs, General Electric's research lab in Schenectady, NY, and Xerox's Palo Alto Research Center. During this era, industry operated on a "closed innovation" model, in which every step of the value chain –from conception of an idea, to research and development, to manufacture of a product and sales and customer support–was done within a single company.

But since the end of the Cold War, the large industrial labs have collapsed. Now, information flows more freely between different companies, between industry and universities, and across national boundaries. Industry now operates on an "open innovation" model, in which different parts of the innovation process happen at different places. Companies partner with researchers in other companies, in universities, and in other countries.

"When I did research on organic materials that got turned into a product, that whole value chain existed inside Xerox," says Duke. But that would never happen nowadays. "You would now have different pieces done in different places," says Duke.

Photo credit: Ernie Tretkoff

Charlie Duke

A threat that Duke worries about now is globalization. The United States is facing increased competition from other counties, including China and India, which are rapidly becoming technologically advanced and have an enormous supply of cheap, educated labor. China produces more engineers a year than we have in the entire country, Duke points out. The United States is in danger of falling behind in science and technology.

As this happens, more and more jobs will be outsourced, Duke predicts. (He even commented that APS could save money by having this article written by someone in Mongolia instead of here in College Park, Maryland)

"The pace of change is speeding up and the US is falling further and further behind," says Duke. "It's a big deal. It makes the fall of the large industrial labs look like a pin prick."

Duke doesn't claim to have a solution, but he is certain that the country is not paying enough attention to the looming threat. "The US government in my view is just distracted. The war in Iraq is a side show. This country is running on empty," he says.

"People blow up cars in Baghdad, and that gets a lot of press coverage, but when you look at the global economy, that's the end of life as the American middle class knows it."

Scientists, Teachers, Clergy Hail Court Ruling

Scientists and nonscientists alike applauded a US district court ruling in December that a school board violated the Constitution by requiring high school science students to learn about "intelligent design," the idea that living species formed through the intervention of a supernatural designer. The decision shows that the US will maintain a strong science curriculum, which will help the US stay competitive in science and technology, experts say. According to others, the decision underlines that intelligent design is a disguised form of religious creationism, one that is promoted by organized public-relations strategies instead of research in scientific journals.

The US District Court in Harrisburg, Pennsylvania ruled that the York County (PA) school board violated the Constitution's principle to separate government and religion by requiring a four-paragraph statement to be read to high-school science students. The statement attacked evolution, the cornerstone of modern biology, and promoted intelligent design as an alternative to evolution.

Judge Jones wrote in his decision, "We hold that the ID Policy is unconstitutional pursuant to the Establishment Clause of the First Amendment of the United States Constitution and Art. I, Section 3 of the Pennsylvania Constitution."

"History shows that attempts to push creationism in the public schools don't go away, they just adapt to the legal circumstances," said Eugenie Scott, Executive Director, National Center for Science Education, which monitors intelligent design activity in the US "It is already clear that the new slogan for the ID movement is going to be 'Teach the Controversy!'– even though there is no scientific controversy over the validity of evolution in biology."

"Calls to 'teach both sides' of a controversy that does not exist would lead to the inclusion of non-scientific and anti-scientific doctrines in the classroom, and would dramatically weaken American science education," said Ken Miller, a Brown University biology professor who is the author of widely-used high school biology textbooks.

The decision will improve K-12 science education and thereby help the US stay competitive in science and technology, said Marshall Berman, a retired government scientist who has served as vice president for the New Mexico State Board of Education. "The US is falling rapidly and drastically behind other countries in science and math education," Berman says. Without a much stronger focus on science, "US competitiveness is almost certainly destined to be second-class," he says. The decision, says Berman, makes very good sense economically, scientifically and constitutionally. It sends the message that the US is focused on better science education.

Berman's back page article on the subject in the October 2005 *APS News* helped keep ID out of classrooms in the Minnetonka school district in Minnesota. Carol Eastlund, a school board member, quoted from Berman's article in her remarks to the Minnetonka Board of Education in December.

Despite arguments to the contrary, evolution and religion can co-exist harmoniously, some clergy members say.

"There is no conflict between evolution and belief in God, but evolution belongs in the science classroom and theology, biblical or not, belongs in philosophy or religious discussions," said Charles W. Holsinger, an ordained Presbyterian minister who lives in Seven Valleys, Pennsylvania, in southern York County. "Belief in God should not stifle curiosity and research by assuming God is the answer to anything. The miracle and wonder of the natural world, including evolution, led me to believe in a God."

–Courtesy of Inside Science News Service

TAIWAN SYMPOSIUM CONTINUED FROM PAGE 1

cultural evening, sightseeing tours in Taipei and the surrounding area, and an awards ceremony honoring the students' achievements in physics.

"The symposium in Taiwan was the most exciting event I have ever participated in. From meeting famous physicists to discussing physics subjects with students from all over the world, it will forever influence my love of physics and has convinced me that I want to study physics in college," said Franz Sauer, one of the US physics young ambassadors.

About 300 students participated in the United States Physics Talent Search, according to US organizer Andrew Gavrin of Indiana University-Purdue University Indianapolis. The talent search ran during 2005 as a way to create enthusiasm, interest, and participation in physics among young people and their families. Participants earned points by completing projects related to physics, such as writing an essay, doing a physics experiment, visiting a physics lab, or attending a World Year of Physics event. The talent search was intended to be inclusive, not competitive, said Gavrin.

Students who earned 10 points were recognized as "United States Physics Talent." Higher numbers of points earned students "International Honorable Mention" awards. The girl and boy in each age group with the most points became "Physics Young Ambassadors," and were invited to attend the symposium in Taiwan.

The symposium and the talent search helped students understand what physics is about, and encouraged the students to continue learning about physics, said Gavrin. "Every one of them said something about how wonderful it was and how inspired they were to do more physics."

The US students who participated in the Physics Young Ambassador's symposium were:

Franz Sauer
High Technology High School
Lincroft, New Jersey

Kelsey Duncan
J.P. McConnell Middle School
Loganville, Ga.

Amy Abramowitz
Myers Park High School
Charlotte, NC

Daniel Duncan
Millburn School
Wadsworth, IL
(also Antioch Community High School, Antioch, IL)

Alexandra Vinegar
Chapel Hill High School
Chapel Hill, NC

Letters

Berman's Back Page Defended

Marshall Berman's call to arms against the pernicious doctrine of creationism ("Back Page", October, 2005) deserves more support than it receives in the December, 2005 Letters.

Creationist attacks on the theory of evolution, arising because of its incompatibility with a literal interpretation of the early chapters of Genesis, stir up a wide range of scientific defenders, some of whom overstate their case by assigning to evolutionary theory a greater certainty than it merits. So J. W. Lane, in identifying these overstatements as the source of all the furor, has misconstrued an effect as the cause.

Edward J. Garboczi's fatuous suggestion that scientists should ignore all statements by religious believers raises the question of why many who accept the scientific pronouncements of, for example, Newton reject his religious beliefs. The answer of course is that observational and experimental support is offered for the former but not for the latter.

John G. Fletcher
Livermore, CA

Science Reporting or Junk Writing?

I read with amused distress the two articles "Living the (Scientific) American Dream" and "Science matters at USA Today" in your November 2005 issue. The first, with dramatic verve, the second, with lyrical eloquence, assures us that is is possible to become a single universal genius who upon need and command is capable of writing meaningful, nay, inspiring reports on all scientific topics, from quark confinement to laser technology, from polymer science to molecular genetics, etc., all the way to cosmology.

To achieve such a feat, one ought to be something like Lavoisier, Darwin, Planck, Einstein, Heisenberg, Crick, Hubble etc. combined. This cannot be achieved by human beings, not even if they are supported by the APS. The outcome of such an enterprise is at best a hotchpotch, mixed with PR publicity propaganda, "gee-whiz" show biz, as we are, sadly, accustomed to from our papers and journals. Even reading editorial short-reviews published in *Physics Today*, one sometimes feels that the reporter went beyond his ken and did not quite understand the topic.

More importantly, such junior-high-school-science-inspired articles may entice inquisitive kids to "take up science", but finding out that this requires specific concentration and that miracles are rare, they will soon drop it. (I have examples of this even in my family.) And whether politicians (from whom the money comes) will be impressed to dip into their (i.e. the public's) pockets, is very doubtful.

When I was very young, in communist Hungary, I occasionally acted as a science writer to supplement my meager and uncertain income as an assistant professor. I remember the agony (not elation!) I went through when I had to write about a topic which, though in my field of theoretical physics, was not really in my area of active competence. But then, this was almost 60 years ago. Standards are now different.

If we want to (as we must) make young people and the mysterious "public" more conscious of the role which science plays in humanism and society, we must find better methods than propaganda journalism. I became a scientist because first, my father inspired me; and second, because when I was 10, I asked for and got a chemistry set for Christmas. It was only after that that I started reading well-written, single-topic popular science books – the few which then existed both in my mother tongue and foreign languages. And finally, I had a well-versed scientist as my physics and math teacher in senior high school. (Eventually he became a professor at the University and I got my PhD under his guidance.) Nowadays we indulge our children with TV's, computer games, cell-phones. Something is wrong here.

Paul Roman
Ludenhausen, Germany

MEMBERS IN THE MEDIA CONTINUED FROM PAGE 2

"The world is not as real as we think. My personal opinion is that the world is even weirder than what quantum physics tells us."

–Anton Zeilinger, University of Vienna, on quantum weirdness, The New York Times, December 27, 2005

"Astronomers wanted a time scale that represented the Earth's movement, and the clock community wanted a smooth scale. The compromise has become increasingly difficult to maintain."

–Judah Levine, NIST/University of Colorado, on leap seconds, The Washington Post, December 26, 2005

"In between 2003 and 2005 there has been a tipping point. All of the buzz is about nanotechnology. The physics of silicon can carry us only so far."

–Philip Kuekes, Hewlett-Packard Laboratories, on the switch from silicon technology to nanotechnology, The New York Times, December 29, 2005

"If this equation were found to be even slightly incorrect, the impact would be enormous - given the degree to which [it] is woven into the theoretical basis of modern physics and everyday applications. This doesn't mean [the relation] has been proven to be completely correct. Future physicists will undoubtedly subject it to even more precise tests because accurate checks imply that our theory of the world is in fact more and more complete."

–David Pritchard, MIT, on precise tests of $E=mc^2$, Christian Science Monitor, December 29, 2005

Viewpoints...

New Website Lets Visitors Assess "Female-friendliness" of Graduate Departments

By Marc Sher

A key date for Graduate Admissions Directors is April 15th. In addition to being the federal tax deadline, it is the date by which admitted students must commit to attending their choice of graduate schools. Between now and then, undergraduate seniors (and those reentering physics) will be scouring web pages, talking to friends, faculty and advisors, and visiting campuses.

What are the key factors in this decision? There is much more to a graduate school that the quality of the research. Graduate departments are communities in which young adults will spend 5-6 years of their lives. The probability of success depends in large part on the atmosphere in the department We've all heard horror stories of institutions with unfriendly climates, in which students are treated poorly and without much respect. For women especially, attending a school with a warm and nurturing climate can be critical in their career development.

Yet how are students to learn about the climate, especially the climate for women? Web pages generally give very little information and faculty advisors typically know a few people at the institution and can only comment about the research. The campus visits for admitted students are often (but not always) highly scripted affairs ("dog and pony shows"), on weekends, in which only current students with positive things to say meet with the prospective students.

As a member of the APS Committee on the Status of Women in Physics (CSWP), I was interested in giving prospective students a better idea of the climate for women at graduate institutions. Of course, making a list of problem institutions would not be appropriate (certainly not under the APS rubric). Instead, an e-mail was sent to the chairs of roughly two hundred graduate institutions which asked five questions:

1. How many tenure-track or tenured faculty – male/female?
2. How many graduate students?– male/female?
3. Is there a family leave policy for graduate students? If so, describe.
4. Is there family health insurance available for graduate students? Is it included in the stipend?
5. In a paragraph, please describe why someone applying to graduate school who is interested in a female-friendly department should choose your institution.

The first two questions are simple demographics. The next two are designed to give students a good idea as to whether female-friendly policies are already in place (as a result of the survey, several chairs have told me that they hope to institute such policies at their institutions). The final question is much more open-ended.

The response rate was extraordinary. With just an e-mail and one follow-up, we now have had responses from the chairs, or their designees,

Female friendly continued on page 11

World Year of Physics Just the Beginning

By Alan Chodos

Amid the revelry this past New Year's Eve, the World Year of Physics quietly passed into history. It's worth taking a few moments to review what was accomplished, and to look ahead to the great deal that still needs to be done.

APS took the lead in promoting WYP activities throughout the US. One of our most important tasks was simply to get the word out to the physics community nationwide, and we're pleased to note that over 600 events were recorded on our event finder at www.physics2005.org ; since not all events found their way to our event finder, this probably means that there were in the neighborhood of 1000 outreach events organized at the local level under the rubric of the World Year of Physics.

With funding from the NSF, the DOE's Office of Science, and NIST, APS also organized its own WYP projects. Two of them were aimed specifically at schools: the Eratosthenes project for high schools, for which over 700 high school classrooms signed up in the spring of 2005; and the PhysicsQuest project for middle schools, which garnered about 5000 participating classrooms in each of the spring and fall semesters of 2005.

In addition, we were able to devote $200,000 to finance 20 "Physics on the Road" teams across the country. We had to choose from among close to 40 excellent applications, and we were reminded of the tremendous talent and enthusiasm for this kind of outreach that can be unleashed with a small amount of financial support.

We also helped to launch "Einstein@home," a project with real scientific potential, that uses data from LIGO and GEO to search for gravitational waves. Alas, gravitational waves were not found in 2005, but the project continues and the search goes on. We sponsored an "Adopt-a-Scientist" program that brings high school classes into contact with scientists in industry and academia. We commissioned a work of art, *A New World View*, celebrating Einstein's achievements; details can be seen at www.physicsmatters.org.

Those are some of the highlights. I'm pleased to say that APS is extending PhysicsQuest as an ongoing annual project. Einstein@home and Adopt-a-Scientist are continuing, and we hope *A New World View* will have a lasting impact as well. But as David Harris points out in the January issue of *Symmetry*, all of these efforts, in a country the size of the US, cannot compete for very much of the attention of the average citizen. If you stop a random person in the street (or even on a university campus) and ask if they have heard anything about the World Year of Physics, the answer will almost certainly be no.

The good news is that therefore there is much opportunity for additional public outreach. The World Year of Physics was a valuable springboard to get the physics community more engaged with the public. But the effort has barely taken off, and we need to continue to be creative and proactive as we tell the story of the importance and excitement of physics.

As the Associate Executive Officer of APS, Alan Chodos was heavily involved in the Society's World Year of Physics activities.

Einstein and the World Year of Physics

The fact that the World Year of Physics celebrated the centennial of Einstein's miracle year turned out to be a mixed blessing. On the positive side, since more people have heard of Einstein than have any idea what physics is all about, it was frequently possible to use Einstein as a way of beginning a conversation about physics.

The downside is that all too often the conversation stopped with Einstein. Much of the media attention naturally focused on the man with the deep-set eyes and untamed hair. Many of the public events concentrated more on Einstein's achievements than on the promise of new discoveries.

Einstein of course deserved the accolades he received. But to become a physicist or to be interested in understanding the physical world one doesn't necessarily have to be an Einstein. Despite our best efforts, that message, important to students and the public alike, did not always get through. *–A.C.*

Physics News in 2005

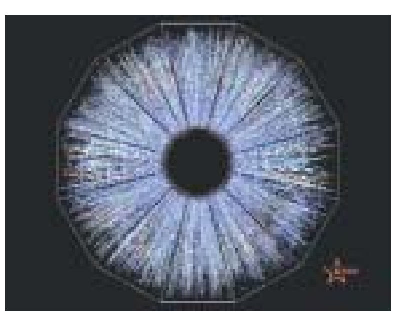
A Supplement to *APS News*

Edited by Phillip F. Schewe, Ben Stein and Ernie Tretkoff

INTRODUCTION

Physics News in 2005, 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/.

AN OCEAN OF QUARKS



Courtesy of Brookhaven National Laboratory

Nuclear physicists have demonstrated that the material essence of the universe at a time mere microseconds after the big bang consists of a ubiquitous quark-gluon liquid. This insight comes from an experiment carried out over the past five years at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Lab, where scientists have created a toy version of the cosmos amid high-energy collisions. RHIC is, in effect, viewing a very early portion of the universe, before the time when protons are thought to have formed into stable entities (ten microseconds after the big bang).

In our later, cooler epoch quarks conventionally occur in groups of two or three, held together by gluons. Could a nucleus be made to rupture and spill its innards into a common swarm of unconfined quarks and gluons? This is what RHIC set out to show.

In the RHIC accelerator two beams of gold ions are clashed at several interaction zones around the ring-shaped facility. Every nucleus is a bundle of 197 protons and neutrons, each of which shoots along with an energy of up to 100 GeV. When the two gold projectiles meet in a head-on "central collision" event, the total collision energy is 40 TeV. Of this, typically 25 TeV serves as a stock of surplus energy–call it a fireball–out of which new particles can be created. Indeed in many gold-gold smashups as many as 10,000 new particles are born of that fireball.

The outward-streaming particles provided the tomographic evidence for determining the properties of the fireball. The recreation of the frenzied quark era lasts only a few times 10^{-24} seconds. The size of the fireball is about 5 femtometers, its density about 100 times that of an ordinary nucleus, and its temperature about 2 trillion degrees Kelvin or 175 MeV. But was it the much-anticipated quark-gluon plasma? The data unexpectedly showed that the fireball looked nothing like a gas. For one thing, potent jets of mesons and protons expected to be squirting out of the fireball were being suppressed.

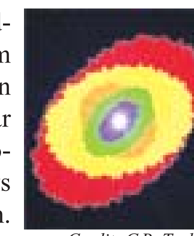
For the first time since starting nuclear collisions at RHIC in the year 2000 and with plenty of data in hand, all four detector groups operating at the lab have converged on a consensus opinion. They believe that the fireball is a liquid of strongly interacting quarks and gluons rather than a gas of weakly interacting quarks and gluons. The liquid is dense but seems to flow with very little viscosity, approximating an ideal fluid. The RHIC findings were reported at the April meeting of the American Physical Society in Tampa.

Papers published concurrently by the four groups: BRAHMS: *Nucl.Phys. A* 757 (2005) PHENIX: 1-27, *Nucl.Phys. A* 757 (2005) 28-101, PHOBOS: *Nucl.Phys. A* 757 (2005) 102-183, STAR *Nucl. Phys. A* 757 (2005) 184-283

THE MOST DISTANT CRAFT LANDING IN THE SOLAR SYSTEM

The Huygens probe, given long passage by the Cassini spacecraft into the middle of Saturn's minor planetary system, has successfully parachuted onto the surface of Titan, the only moon with a considerable atmosphere. Pictures taken from miles above the surface during the descent and pictures taken on the surface itself suggest the presence of boulders or ice chunks and some kind of shoreline, perhaps of a hydrocarbon lake or sea. The data gained so far include a sort of acoustic sampling of the atmosphere during the descent and some color photographs. The Titan probe is named for Christiaan Huygens, who first spotted Titan and who also was the first to provide the proper interpretation of Saturn's ring system. (http://www.esa.int/SPECIALS/Cassini-Huygens/)

THE BIGGEST SPLASH OF LIGHT FROM OUTSIDE THE SOLAR SYSTEM



Credit: G.B. Taylor, NRAO/AUI/NSF)

The biggest splash of light from outside the solar system to be recorded here at Earth occurred on December 27, 2004. The light came from an object called SGR 1806-20, about 50,000 light years away in our own galaxy. SGR stands for "soft gamma repeater," a class of neutron star possessing a gigantic magnetic field. Such "magnetars" can erupt violently, sending out immense bolts of energy in the form of gamma rays and light at other wavelength regions of the electromagnetic spectrum. The eruption was first seen with orbiting telescopes at the upper end of the spectrum over a period of minutes and then by more and more telescopes; at radio wavelengths emissions were monitored for months. For an instant the flare was brighter than the full moon. (NASA press conference, 18 February; www.nrao.edu/pr/2005/sgrburst/; many telescopes participated in the observations, reports appeared in the 28 April 2005 issue of *Nature*.)

SUPERFLUID SOLID HYDROGEN

Last year Moses Chan (Penn State) announced the results of an experiment in which solid helium-4 was revolved like a merry-go-round. It appeared that when the bulk was revolved at least part of the solid remained stationary. In effect part of the solid was passing through the rest of the solid without friction. Chan interpreted this to mean that a fraction of the sample had become superfluid.

Now, Chan sees evidence for superfluid behavior in solid hydrogen as well. Speaking at the March meeting of the American Physical Society in Los Angeles, Chan said that his hydrogen results are preliminary and that further checks are needed before ruling out alternative explanations. The concept of what it means to be a solid, Chan said, needs to be re-examined.

DIRECT DETECTION OF EXTRASOLAR PLANETS

Credit:: NASA/JPL-Caltech/R. Hurt (SSC))

Direct detection of extrasolar planets has been achieved for the first time. Previously the existence of planets around other suns has been inferred from subtle modulation of the light emitted by the star. Now light from the planet itself has been recorded directly at infrared wavelengths by the Spitzer Space Telescope (www.spitzer.caltech.edu).

The planets, one with the prosaic name of HD 209458b (153 light years away), the other TrES-1 (489 light years away), orbit their stars more tightly than does Mercury around our sun. This makes the Jupiter-sized planets hot enough to be viewed by Spitzer. (NASA press conference, 23 March; report published in *Nature*, 7 April.)

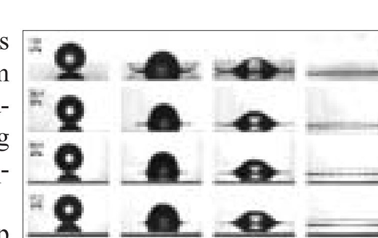
ZEPTOGRAM MASS DETECTION–WEIGHING MOLECULES

Michael Roukes and his Caltech colleagues have performed mass measurements with nearly zeptogram (zg) sensitivity, that is, with an uncertainty of only a few times 10^{-21} grams. At this level one can start to weigh molecules one at a time. In experiments, the presence of xenon accretions of only about 30 atoms (7 zg, or about 4 kilodaltons, or the same as for a small protein) have been detected in real time.

Minuscule masses are measured through their effect on an oscillating doubly clamped silicon carbide beam, which serves as the frequency-determining element in a tuned circuit. In practice, the beam would be set to vibrating at a rate of more than 100 MHz and then would be exposed to a faint puff of biomolecules. Each molecule would strike the beam, where its presence (and its mass) would show up as a changed resonant frequency.

After a short sampling time, the molecule would be removed and another brought in. Through this kind of miniaturization and automation, the NEMS approach to mass spectroscopy could change the way bioengineering approaches its task, especially in the search for cancer and its causes. The Roukes group reported its findings at the APS March Meeting in Los Angeles.

NO SPLASH ON THE MOON



Sidney Nagel's lab at the University of Chicago has explored the behavior of liquid drops when they fall from a faucet. At the APS March meeting, Nagel's graduate student, Lei Xu, revealed a surprising discovery concerning one of the commonest physical effects: the splash a liquid drop makes when it strikes a flat surface.

Under ordinary atmospheric conditions a liquid drop will flatten out on impact, splay sideways, and also raise a tiara-like crown of splash droplets. Remove some of the ambient atmosphere, and surprisingly the splash becomes less. At about one-fifth atmosphere the splash disappears altogether, leaving the outward going splat but no upwards splash. Apparently it is the presence of the air molecules that give the impacting liquid something to push off of; remove the surrounding atmosphere, and the splash disappears. (Lei Xu, Wendy W. Zhang, and Sidney R. Nagel, *Phys. Rev. Lett.* 94, 184505, 2005)

PYROFUSION: A ROOM-TEMPERATURE, PALM-SIZED NUCLEAR FUSION DEVICE

A room-temperature, palm-sized nuclear fusion device has been reported by a UCLA collaboration, potentially leading to new kinds of fusion devices and other novel applications such as microthrusters for MEMS spaceships.

The key component of the UCLA device is a pyroelectric crystal, a class of materials that includes lithium niobate, an inexpensive solid that is used to filter signals in cell phones. When heated, a pyroelectric crystal polarizes charge, segregating a significant amount of electric charge near a surface, leading to a very large electric field there. In turn, this effect can accelerate electrons to relatively high (keV) energies.

The UCLA researchers (Brian Naranjo, Jim Gimzewski, Seth Putterman) take this idea and add a few other elements to it. In a vacuum chamber containing deuterium gas, they place a lithium tantalate ($LiTaO_3$) pyroelectric crystal so that one of its faces touches a copper disc which itself is surmounted by a tungsten probe. They cool and then heat the crystal, which creates an electric potential of about 120 kilovolts at its surface.

The electric field at the end of the tungsten probe tip is so high (25 V/nm) that it strips electrons from nearby deuterium atoms. Repelled by the positively charged tip, and crystal field, the resulting deuterium ions then accelerate towards a solid target of erbium deuteride (ErD_2), slamming into it so hard that some of the deuterium ions fuse with deuterium in the target. Each deuterium-deuterium fusion reaction creates a helium-3 nucleus and a 2.45 MeV neutron, the latter being collected as evidence for nuclear fusion. In a typical heating cycle, the researchers measure a peak of about 900 neutrons per second, about 400 times the "background" of naturally occurring neutrons. During a heating cycle, which could last from 5 minutes to 8 hours depending on how fast they heat the crystal, the researchers estimate that they create approximately 10^{-8} joules of fusion energy. By using a larger tungsten tip, cooling the crystal to cryogenic temperatures, and constructing a target containing tritium, the researchers believe they can scale up the observed neutron production 1000 times, to more than 10^6 neutrons per second. (Naranjo, Gimzewski, Putterman, *Nature*, 434, 1115).

MOST PRECISE MASS CALCULATION FOR LATTICE QCD

A team of theoretical physicists have produced the best prediction of a particle's mass, using lattice QCD, a computational approach to understanding how quarks interact. Within days of their paper being submitted to Physical Review Letters, that very particle's mass was accurately measured at Fermilab, providing striking confirmation of the predicted value.

In a lattice QCD computation, quarks are placed at the interstices of a crystal-like structure. The quarks interact with each other via the exchange of gluons along the links between the quarks. From this sort of framework the mass of the known hadrons can be calculated.

Until recently, however, the calculations were marred by a crude approximation. A big improvement came in 2003, when uncertainties in mass predictions went from the 10% level to the 2% level. Progress has come from a better treatment of the light quarks and from greater computer power. The improvements provide the researchers with a realistic treatment of the "sea quarks," the virtual quarks whose ephemeral presence has a noticeable influence over the "valence" quarks that are considered the nominal constituents of a hadron. Now, for the first time, the mass of a hadron has been predicted with lattice QCD.

Andreas Kronfeld and his colleagues at Fermilab, Glasgow University, and Ohio State report a mass calculation for the charmed B meson Bc, consisting of an anti-bottom quark and a charmed quark). The value they predict is 6304 +/- 20 MeV. A few days after they submitted their Letter for publication, the first good experimental measurement of the same particle was announced: 6287 +/- 5 MeV. This successful confirmation is exciting because it bolsters confidence that lattice QCD can be used to calculate many other properties of hadrons. (Allison et al., *Phys. Rev. Lett.* 94, 172001, 2005)

PRECISE MEASUREMENT OF THE WEAK NUCLEAR FORCE

Physicists at the SLAC accelerator have measured, with much greater precision than ever before, the variation in the weak nuclear force over an enormous size scale (a distance of more than ten proton diameters) for so feeble a force. Although the results were not surprising (the weak force diminished with distance as expected) this new quantitative study of the weak force helps to cement physicists' view of the sub-nuclear world.

Physicists at SLAC extract weak effects from the much larger electromagnetic effects involved when two electrons interact. In the case of their present experiment (E158), a powerful electron beam scatters from electrons bound to hydrogen atoms in a stationary target. By using electrons that have been spin polarized–the weak force can be studied by looking for subtle asymmetries in the way electrons with differing polarizations scatter from each other.

One expects an intrinsic fall off in the weak force with the distance between the electrons. It should also fall off owing to the cumbersome mass possessed by the Z boson. Finally, the weak force weakens because the electron's "weak charge" becomes increasingly shielded owing to a polarization of the vacuum–with virtual quarks, electrons, and W and Z bosons needing to be taken into account.

Previously, the weak charge has been well measured only at a fixed distance scale, a small fraction of the proton's diameter. The SLAC result over longer distances confirms the expected falloff. According to E158 researcher Yury Kolomensky, the result is precise enough to rule out certain theories that invoke new types of interactions, at least at the energy scale of this experiment. (Anthony et al., *Phys. Rev. Lett*. 95, 081601, 2005)

SUPERFLUIDITY IN AN ULTRACOLD GAS OF FERMION ATOMS

Superfluidity in an ultracold gas of fermion atoms has been demonstrated in an experiment at MIT, where an array of vortices has been set in motion in a molecular Bose Einstein condensate (BEC) of paired lithium-6 atoms. There have been previous hints of superfluidity in Li-6, but the presence of vortices observed in the new experiment clinches the case since vortices manifest the most characteristic feature of superfluidity, namely persistent frictionless flow.

Wolfgang Ketterle and his MIT colleagues use laser beams to hold the chilled atoms in place and separate laser beams to whip up the vortices. Gaseous Li-6 represents only the second known superfluid among fermi atoms, the other being liquid helium-3. There are great advantages in dealing with a neutral superfluid in dilute gas form rather than in liquid form: in the gas phase (with a material density similar to that of the interstellar medium), inter-atomic scattering is simpler; furthermore, the strength of the pairing interaction can be tuned at will using an imposed external magnetic field.

The ultracold lithium gas represents, in a narrow sense, the first "high-temperature" superfluid. Consider the ratio of the critical temperature (T_c) at which the superfluid transition takes place to the fermi temperature (T_f), the temperature (or energy, divided by Boltzmann's constant) of the most energetic particle in the ensemble. For ordinary superconductors, T_c/T_f is about 10^{-4}; for superfluid helium-3 it is 10^{-3}; for high-temperature superconductors 10^{-2}; for the new lithium superfluid it is 0.3. (Zwierlein et al., *Nature*, 23 June 2005)

ULTRAVIOLET FREQUENCY COMB

Physicists at JILA, the joint institute of NIST and the University of Colorado, have created a new optical process to extend the production of coherent radiation into the extreme ultraviolet region of the electromagnetic spectrum. This process takes advantage of the fact that ultrafast laser pulses of femtosecond widths, separated by nanoseconds, manifest themselves as a superposition of light at different frequencies over a wide spectral band.

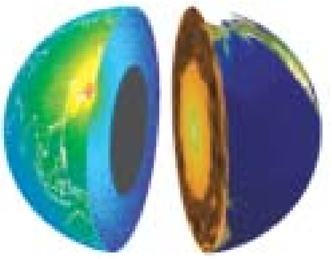
The Fourier transform of these short pulses is a long series of evenly spaced spikes that look like the tines of a comb. The JILA researchers have pushed the coverage of the frequency comb into the extreme ultraviolet by generating a series of high harmonics of the original, near-infrared laser frequency comb. (A comparable result has also been achieved by Ted Hänsch's group in Munich.)

In the JILA experiment, 50-femtosecond-long pulses, spaced 10 nanoseconds apart, are sent into a coherent storage device–an optical buildup cavity. The cavity length is determined so that each tine of the incoming frequency comb is matched to a respective cavity resonance mode. In other words, the pulse train is matched exactly into the cavity such that a pulse running around inside the cavity is reinforced by a steady stream of incoming pulses. After a thousand roundtrips through the cavity, the infrared laser light becomes sufficiently energized to directly ionize xenon atoms inside the cavity. The quick repatriation of the xenon electrons to their home atoms produces light pulses of high frequency harmonics. Coherent high harmonic generation has been achieved with other techniques, typically involving single, actively amplified, ultrashort laser pulses.

The new approach demonstrated in the JILA work has drastically improved the spectral resolution of these high harmonic generated light sources by many orders of magnitude and will also permit an important increase of the efficiency of the harmonic generation process. Moreover, the buildup of intense UV happened without the need for expensive or bulky amplifying equipment.

Optical frequency combs have led to demonstrations of optical atomic clocks and are furthering research in extreme nonlinear optics, precision spectroscopy, and laser pulse manipulation and control. Jun Ye and his colleagues believe that the new ultraviolet frequency comb promises to provide an important tool for ultrahigh resolution spectroscopy and precision measurement in that spectral domain. It will open the door to unprecedented spectral resolution, making it possible for scientists to study the fine structure of atoms and molecules with coherent XUV light. (Jones et al., *Phys. Rev. Lett*. 94, 193201, 2005)

GEONEUTRINOS DETECTED



Neutrinos have very little mass and interact rarely, but are made in large numbers inside the sun as a byproduct of fusion reactions. They are also routinely made in nuclear reactors and in cosmic ray showers. Terrestrial detectors (usually located underground to reduce the confusing presence of cosmic rays) have previously recorded these various kinds of nu's.

Now, a new era in neutrino physics has opened up with the detection of electron antineutrinos coming from radioactive decays inside the Earth. The Kamioka liquid scintillator antineutrino detector (KamLAND) in Japan has registered the presence of candidate events of the right energy; uncertainty in the model of the Earth's interior makes the exact number vague, but it might be dozens of geo-nu's.

The neutrinos presumably come from the decays of U-238 or Th-232. They are sensed when they enter the experimental apparatus, where they cause a 1000-ton bath of fluid to sparkle. Scientists believe the Earth is kept warm, and tectonic plates in motion, by a reservoir of energy deriving from two principal sources: residual energy from the Earth's formation and additional energy from subsequent radioactive decays. The rudimentary inventory of geoneutrinos observed so far is consistent with the theory. (Araki et al., *Nature* 436, 499-503 (28 July 2005)

ATOM-MOLECULE DARK STATES

Physicists at the University of Innsbruck have demonstrated that atom pairing in Bose-Einstein condensates (BECs) using photoassociation is coherent. Coherent pairing of atoms has been observed before using a tuned magnetic condition–a Feshbach resonance–between the atoms. But molecules made that way are only feebly attached. By contrast the process of photoassociation–i.e. using light to fuse two atoms into one molecule–allows more deeply bound molecule states to be established. The trouble is that the same laser light can also be absorbed to dissociate the molecules. The countermeasure used by the Innsbruck researchers is to create a "dark state" in which the light cannot be absorbed. A dark state is a special quantum condition: it consists of three quantum energy levels, two stable ground states and one excited level. If laser light at the two frequencies needed for the transitions from both the ground states to the excited state are present simultaneously, the two excitations (from the two lower energy states) can destructively interfere with each other if there is phase coherence between the ground states. The consequence is that no light gets absorbed and the molecules are stable. Such "electromagnetically induced transparency" has been observed before for transitions within atoms, but the Innsbruck scientists are the first to use it for a transition between a BEC of atoms and molecules. In their experiments, the same (two-color) laser light that creates the dark state is also the light that photoassociates rubidium atoms into molecules. Johannes Hecker Denschlag says that atom-molecule dark states are a convenient tool to analyze the atom-molecule system and to optimize the conversion of atomic into molecular BECs. BECs of ultracold molecules represent, because of their many internal degrees of freedom (vibrational and rotational), a new field of research beyond atomic BECs. (Winkler et al., *Phys. Rev. Lett*. 95, 063202, 2005)

HOW EFFECTIVE WILL FLU VACCINE BE?

A new way of predicting the flu vaccine's efficacy by using the tools of statistical physics was described by Michael Deem of Rice University at the APS March Meeting.

To predict efficacy, researchers examine each strain's hemagglutinin (H) protein, the major protein on the surface of influenza A virus that is recognized by the immune system.

In one standard approach, researchers study all the mutations in the entire H protein from one season to the next. In another approach, researchers study the ability of antibodies produced in ferrets to recognize either the vaccine strain or the mutated flu strain, which had been thought to be a good method for predicting flu vaccine efficacy in humans.

However, these approaches are only modestly reliable indications of the vaccine's efficacy. Deem and his Rice University colleagues point out that each H protein has 5 "epitopes," antibody-triggering regions mutating at different rates. The Rice team refers to the one that mutates the most as the "dominant" epitope. Drawing upon theoretical tools originally developed for nuclear and condensed-matter physics, the researchers focus on the fraction of amino acids that change in the dominant epitope from one flu season to the next.

Analyzing 35 years of epidemiological efficacy data, the researchers believe that their focus on epitope mutations correlates better with vaccine efficacy than do the traditional approaches. Deem and his colleagues Vishal Gupta and Robert Earl believe that this new measure may prove useful in designing the annual flu vaccine and in interpreting vaccine efficacy studies.

DID YOU SAY HYDROPHOBIC WATER?

Hydrophobic water sounds like an impossibility. Nevertheless, scientists at Pacific Northwest National Lab have produced and studied monolayers of water molecules (resting on a platinum substrate) which prove to be poor templates for subsequent ice growth. Picture the following sequence: at temperatures below 60 K, isolated water molecules will stay put when you place them on a metallic substrate. At higher temperatures, the molecules become mobile enough to begin forming into tiny islands of two-dimensional ice. New molecules landing on the crystallites will fall off the edges into the spaces between the islands. In this way the metal surface becomes iced over completely with a monolayer. But because the water molecules' four bonds are now spoken for (1 to the Pt substrate and 3 to their neighboring water molecules), the addition of more water does not result in layer-by-layer 3D ice growth. Only when there is an amount of overlying water equivalent to about 40 or 50 layers does 3D crystalline ice completely cover the hydrophobic monolayer. The PNL researchers are the first to observe this effect. For the novel hydrophobic property to show itself, the water-substrate bond has to be strong enough to form a stable monolayer. Weaker bonding results in a "classic" hydrophobic state, in which the water merely balls up immediately; in other words, not even a first monolayer of ice forms. This research should be of interest to those who, for example, study the seeding of clouds, where ice is nucleated on particles in the atmosphere. (Kimmel et al. *Phys. Rev. Lett*. 95, 166102, 2005)

THE 2005 NOBEL PRIZE IN PHYSICS

The 2005 Nobel Prize in Physics was devoted to optics, with half of the prize going to Roy J. Glauber of Harvard University for his quantum theory of optical coherence, and one-quarter each going to John L. Hall (JILA, University of Colorado and National Institute of Standards and Technology, Boulder, CO) and Theodor W. Hänsch (Max Planck Institute for Quantum Optics, Garching, Germany; Ludwig-Maximilians-University, Munich, Germany), for their development of ultra-high-precision measurements of light.

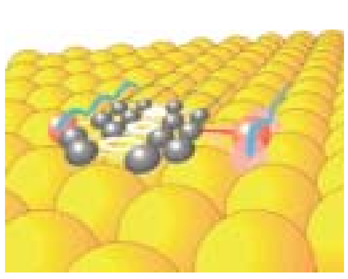
Glauber described optical coherence and the detection of laser light in the language of quantum mechanics. Glauber's theory provided understanding of quantum "noise," jittery and unavoidable fluctuations in the properties of light. This in turn provides information on the limits of measuring light, as well on the as understanding of optical detectors that count single photons at a time. Single-photon detectors are important for applications such as quantum cryptography.

Meanwhile, Hall and Hänsch developed techniques for measuring the frequency of light to what is currently 15 digits of accuracy. These frequency-measurement techniques helped scientists to devise fundamental definitions of physical units (for example, Hall and others helped to redefine one meter as the distance that light travels in 1/299,792,458 seconds). Measuring optical frequency has also helped to test Einstein's theory of special relativity to record-breaking levels of precision. In addition, optical-frequency measurements have made possible tabletop experiments that search for new physics, such as the question of whether the fine structure constant, the quantity that determines the inherent strength of the electromagnetic force, is changing over time.

Hall and Hänsch are cited in particular for the recent development of the "optical frequency comb technique," in which ultrashort pulses of light create a set of equally spaced frequency peaks resembling a comb. The combs can be used to measure other optical frequencies with unprecedented precision and ease (and with much smaller equipment than previously possible). They enable better atomic clocks which in turn can make the Global Positioning System more precise.

WALKING MOLECULES

A single molecule has been made to walk on two legs. Ludwig Bartels and his colleagues at the University of California at Riverside, guided by theorist Talat Rahman of Kansas State University, created a molecule–called 9,10-dithioanthracene (DTA)–with two "feet" configured in such a way that only one foot at a time can rest on the substrate.



Activated by heat or the nudge of a scanning tunneling microscope tip, DTA will pull up one foot, put down the other, and thus walk in a straight line across a flat surface. The planted foot not only supplies support but also keeps the body of the molecule from veering or stumbling off course.

In tests on a standard copper surface, such as the kind used to manufacture microchips, the molecule has taken 10,000 steps without faltering. According to Bartels, possible uses of an atomic-sized walker include guidance of molecular motion for molecule-based information storage or even computation.

DTA moves along a straight line as if placed onto railroad tracks without the need to fabricate any nano-tracks; the naturally occurring copper surface is sufficient. The researchers now aim at developing a DTA-based molecule that can convert thermal energy into directed motion like a molecular-sized ratchet. (Kwon et al. *Phys. Rev. Lett*. 95, 166101, 2005)

PARTICLES OF HEAT

The phonon Hall effect, the acoustic equivalent of the electrical Hall effect, has been observed by physicists at the Max Planck Institut für Festkörperforschung (MPI) and the Centre National de la Recherche Scientifique (CNRS) in France.

In the electrical Hall effect, when an electrical current being driven by an electric field is subjected to an external magnetic field, the charge carriers will feel a force perpendicular to both the original current and the magnetic force, causing the electrical current to be deflected to the side. A "current" of heat can consist of free electrons carrying thermal energy or it can consist of phonons, which are vibrations rippling through the lattice of atoms of the sample.

Previously, some scientists believed that in the absence of free electrons, a magnetically induced deflection of heat could not be possible. The MPI-CNRS researchers felt, however, that a magnetic deflection of phonons was possible, and have demonstrated it experimentally in insulating samples of Terbium Gallium Garnet (a material often used for its magneto-optical properties) where no free charges are present. The sample was held at a temperature of 5 degrees Kelvin and was warmed at one side, creating the thermal equivalent of an applied voltage. Application of a magnetic field of a few Tesla led to an extremely small (smaller than one thousandth of a degree), yet detectable temperature difference. (Strohm et al., *Phys. Rev. Lett*. 95, 155901, 2005)

HYPER-ENTANGLED PHOTON PAIRS

Physicists at the University of Illinois at Urbana-Champaign have demonstrated for the first time the entanglement of two objects not merely in one aspect of their quantum natures, such as spin, but in a multitude of ways.

In the Illinois experiment, two photons are produced in a "down-conversion" process whereby one photon enters an optical crystal and sunders into two lesser-energy correlated daughter photons. The two daughter photons are entangled not just in terms of polarization, but also in a number of other ways: energy, momentum, and orbital angular momentum.

The photon pair can be produced in either of two crystals, and the uncertainty in the production details of the individual photons is what provides the ability to attain entanglement in all degrees of freedom.

Is it better to entangle two particles in ten ways or ten particles in two ways? They're probably equivalent, says Paul Kwiat, leader of the Illinois group, but for the purpose of quantum computing or communication it might be of some advantage if multiple quantum bits (or qubits) of information can be encoded in a single pair of entangled particles. Kwiat says that his lab detects a record two million entangled photon pairs per second with ample determination of numerous properties, allowing a complete characterization of the entanglement produced. (Barreiro et al, *Phys. Rev. Lett*. 95, 260501, 2005)

SUPER LENSING IN THE MID-INFRARED

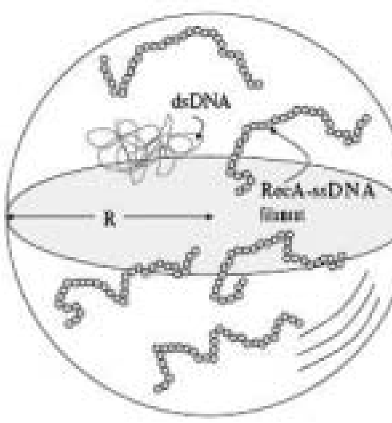
Physicists at the University of Texas at Austin have made a "super lens," a plane-shaped lens that can image a point source of light down to a focal spot only one-eighth of a wavelength wide. This is the first time such super lensing has been accomplished in a functional device in the mid-infrared range of the electromagnetic spectrum.

Historically, lensing required a lens-shaped optical medium for bringing the diverging rays coming from a point source into focus on the far side of the lens. But in recent years, researchers have found that in "negative permittivity" materials, in which a material's response to an applied electric field is opposite that of most normal materials, light rays can be refracted in such a way as to focus planar waves into nearly a point–albeit over a very truncated region, usually only a tenth or so of the wavelength of the light.

Such near-field optics are not suitable for such applications as reading glasses or telescopes, but have become an important technique for certain kinds of nanoscale imaging of large biological molecules than can be damaged by UV light. The micron-sized Texas lens, reported in October at the Frontiers in Optics meeting of the Optical Society of America, consists of a silicon carbide membrane between layers of silicon oxide. It focuses 11-micron-wavelength light, but the researchers hope to push on into the near-infrared range soon. Furthermore, the lensing effect seems to be highly sensitive to the imaging wavelength and to the lens thickness. Possible applications of the lens include direct laser nanolithography and making tiny antennas for mid-IR-wavelength free-space telecommunications.

UNCOVERING NEW SECRETS IN A DNA HELPER

The protein RecA performs some profoundly important functions in bacteria. Two independent papers shed light on how the bacterial protein helps (1) identify and (2) replace damaged DNA while making few mistakes. Error-correction mechanisms keep DNA fidelity during replication to within an average of one error per billion "letters" or base pairs. This research may provide insight on how damage to existing DNA from processes such as UV radiation can be detected and repaired efficiently in living organisms, including humans, who carry evolutionary cousins of RecA. When the double-helix DNA is seriously damaged, single-stranded DNA is exposed and RecA polymerizes (bonds) onto it, activating a biochemical SOS signal.



To do this, Tsvi Tlusty and his colleagues at the Weizmann Institute and Rockefeller University suggest that RecA performs "kinetic proofreading" in which RecA can precisely identify a damaged strand and its length by using ATP (the energy-delivering molecule in cells) to inspect (proofread) the DNA's binding energy and to detach after a certain time delay (the "kinetic" part) if the DNA has the "wrong" binding energy.

The researchers argue that the RecA performs the precise binding and unbinding actions that are necessary for kinetic proofreading through "assembly fluctuations," a protein's structural changes brought about by constant bonding and dissociation of RecA from its target. According to the authors, this is the first known biological process in which kinetic proofreading and assembly fluctuations are combined (Tlusty et al., *Physical Review Letters*, 17 December 2004, *Phys. Rev. Lett*. 93, 258103 (2004)).

Meanwhile, researchers at L'Institut Curie in France (Kevin Dorfman and Jean-Louis Viovy) have studied how RecA exchanges a damaged strand with a similar copy. In bacteria, RecA protein catalyzes this process by binding to a healthy single DNA strand to form a filament that "searches" for damaged double-stranded DNA (dsDNA). At odds with the conventional view, they propose that the dsDNA which needs to be repaired is the more active partner in this mutual search. Unbound, it first diffuses towards the more rigid and thus less mobile filament. In a second step, local fluctuations in the structure of the dsDNA, caused only by thermal motion, allow the base pairs of the filament to align and pair with the strand of replacement DNA. (Dorfman et al, Phys. Rev. Lett. 93, 268102, 2004)

ELECTRON CLOUDS CAN FREEZE INTO AN "ORBITAL GLASS"

Electron clouds can freeze into an "Orbital Glass" at low temperatures. In the modern picture of quantum mechanics, electrons take the form of "clouds" within the atoms and molecules in which they inhabit. The clouds, which have various shapes such as spheres or dumbbells, represent the general boundaries within which one may find an electron at any one measurement in time. Typically, processes involving electron clouds (more formally known as "orbitals") are blazingly fast. In the order of a femtosecond (10^{-15} s), for example, an electron orbital can make transitions between degenerate states (those containing the same amount of energy), transforming from a vertical dumbbell to a horizontal one with respect to some axis.

Now, scientists have found evidence that these and other orbital processes can slow down dramatically–to as long as 0.1 seconds, a slowing by 14 orders of magnitude–for electrons in low-temperature $FeCr_2S_4$, a spinel (class of mineral) with a relatively simple crystalline structure. The researchers, from the Center for Electronic Correlations and Magnetism at the University of Augsburg in Germany (Peter Lunkenheimer) and the Academy of Sciences of Moldova, consider these frozen electron orbitals in spinels to constitute a new class of material which they have dubbed an orbital glass. By measuring the response of the material to alternating-current electric fields in the audio- to radio-frequency range, they found that processes involving non-spherical orbitals dramatically slow down at low temperatures to form a glass-like state, in a manner very similar to the arrest of molecular motion that occurs when glass blowers perform their craft.

It's not just the orbitals that slow down; the neighboring atomic nuclei that surround the electrons also distort more slowly in response to the glacially changing orbitals. In contrast to conventional glasses, a complete "freeze" of the electron clouds does not occur at the lowest temperatures. Completely frozen orbitals are prevented by quantum-mechanical tunneling: the clouds keep themselves moving by making transitions between different low-energy cloud configurations even without the energy they normally require. (Fichtl et al., *Phys. Rev. Lett*. 94, 027601, 2005)

COMPLEX HYBRID STRUCTURES

Complex hybrid structures, part vortex ring and part soliton, have been observed in a Bose-Einstein condensate (BEC) at the Harvard lab of Lene Vestergaard Hau. Hau previously pioneered the technique of slowing and then stopping a light pulse in a BEC consisting of a few million atoms chilled into a cigar shape about 100 microns long.

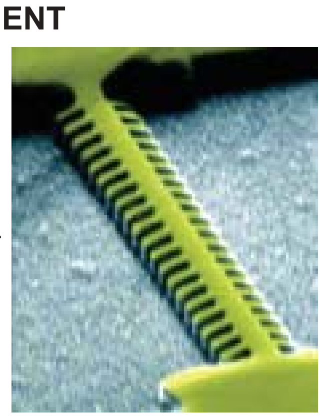
In the new experiment, two such light pulses are sent into the BEC and stopped. The entry of these pulses into the BEC set in motion tornado-like vortices. These swirls are further modulated by solitons, waves which can propagate in the condensate without losing their shape. The resultant envelope can act to isolate a tiny island of superfluid BEC from the rest of the sample.

The dynamic behavior of the structures can be imaged with a CCD camera by shining a laser beam at the sample. Never seen before, these bizarre BEC excitations sometimes open up like an umbrella. Two of the excitations can collide and form a spherical shell (the vortex rings taking up the position of constant latitudes). Two such rings, circulating in opposite directions, will co-exist for a while, but after some period of pushing and pulling, they can annihilate each other as if they had been a particle-antiparticle pair.

Hau and her colleagues, graduate student Naomi Ginsberg and theorist Joachim Brand (at the Max Planck Institute for the Physics of Complex Systems, Dresden), have devised a theory to explain the strange BEC excitations and believe their new work will help physicists gain new insights into the superfluid phenomenon and into the breakdown of superconductivity. (Ginsberg, Brand, Hau, *Phys. Rev. Lett.* 94, 040403, 2005)

EVIDENCE FOR QUANTIZED DISPLACEMENT

Physicists at Boston University have found evidence for quantized displacement in nanomechanical oscillators. They performed an experiment in which tiny silicon paddles, sprouting from a central stick of silicon like the vanes from a heat sink, seem to oscillate together in a peculiar manner: the paddles can travel out to certain displacements but not to others. The setup for this experiment consists of a lithographically prepared structure looking like a double-sided comb.



Next, a gold-film electrode is deposited on top of the spine. Then a current is sent through the film and an external magnetic field is applied. This sets the structure to vibrating at frequencies as high as one gigahertz. This makes the structure the fastest man-made oscillator. At relatively warm temperatures, this rig behaves according to the dictates of classical physics. The larger the driving force (set up by the magnetic field and the current moving through the gold electrode) the greater the excursion of the paddles.

At millikelvin temperatures, however, quantum mechanics takes over. In principle, the energies of the oscillating paddles are quantized, and this in turn should show up as a propensity of the paddles (500 nm long and 200 nm wide) to displace only by discrete amounts. The Boston University experiment sees signs of exactly this sort of behavior. (Gaidarzhy et al., *Phys. Rev. Lett*. 94, 030402, 2005)

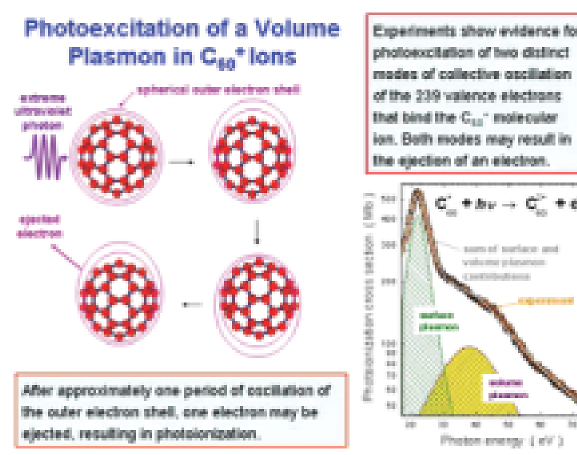
LIQUID CARBON CHEMISTRY

The chemistry of carbon atoms, with their gregarious ability to bond to four other atoms, is a major determinant of life on Earth. But what happens when carbon is heated up to its melting temperature of 5000 K at pressures greater than 100 bars? Although liquid carbon may exist inside the planets Neptune and Uranus, the main interest in studying liquid carbon here on Earth might be in the indirect information provided about bonding in ordinary solid carbon or in hypothetical novel forms of solid carbon. A new experiment creates liquid carbon by blasting a solid sheet of carbon with an intense laser beam. Before the liquid can vaporize, its structure is quickly probed by an x-ray beam. At low carbon density, two bonds seem to be the preferential way of hooking up, while at higher density, three and four bonds are typical.

This is not to say that complex organic molecules (carbon bonded to other atoms such as hydrogen or oxygen) could survive at 5000 K, but carbon bonds are tougher and can persist. The experiment was performed by physicists from UC Berkeley, the Paul Scherrer Institute (PSI) in Switzerland, Lawrence Berkeley National Lab, Kansas State, and Lawrence Livermore National Lab. A team member, Steve Johnson, says that one next step will be to study carbon, as well as other materials, at even higher temperatures in order to look at "warm dense matter," a realm of matter too hot to be considered by conventional solid-state theory but too dense to be considered by conventional plasma theory. (Johnson et al., *Phys. Rev. Lett*. 94, 057407, 2005)

240 ELECTRONS SET IN MOTION

A soccerball-shaped carbon-60 molecule, possessing a mobile team of up to about 240 valence electrons holding the structure together, is sort of halfway between being a molecule and a solid. To explore how all those electrons can move as an ensemble, a team of scientists working at the Advanced Light Source synchrotron radiation lab in Berkeley, turned the C-60 molecules into a beam (by first ionizing them) and then shot ultraviolet photons at them. When a photon is absorbed, the energy can be converted into a collective movement of the electrons referred to as a plasmon.



Previously a 20-electron-volt "surface plasmon" was observed: the absorption of the UV energy resulted in a systematic oscillation of the ensemble of electrons visualized as a thin sphere of electric charge. Now a new experiment has found evidence of a second resonance at an energy of 40 eV. This second type of collective excitation is considered a "volume plasmon" since the shape of the collective electron ensemble is thought to be oscillating with respect to the center of the molecule.

The collaboration consists of physicists from the University of Nevada, Reno, Lawrence Berkeley National Lab, Justus-Liebig-University (Giessen, Germany), and the Max Planck Institute (Dresden). (Scully et al., *Phys. Rev. Lett*. 94, 065503, 2005)

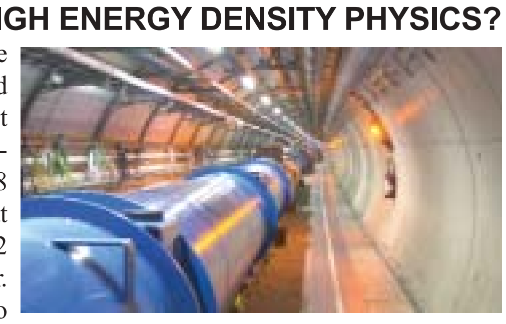
DEGENERATE GAS STUCK IN OPTICAL LATTICE

Physicists at the ETH lab in Zurich have, for the first time, not only made a quantum degenerate Fermi gas but have been able to load the atoms into the criss-cross interstices of an optical lattice, an artificial 3D crystal in which atoms are held in place by the electric fields of well-aimed laser beams.

By adjusting an external magnetic field, the pairs of atoms lodged in their specified sites can be made to interact (courtesy of the "Feshbach resonance") with a varying strength. According to Tilman Esslinger, it is this ability to put atoms where you want them in a crystal-like scaffolding, and then to make them interact with a strength that you can control, that makes this setup so useful. It might be possible to test various condensed matter theories, such as those that strive to explain high-temperature superconductivity, on a real physical system. (Kohl et al., *Phys. Rev. Lett*. 94, 080403, 2005)

USING THE LHC TO STUDY HIGH ENERGY DENSITY PHYSICS?

The Large Hadron Collider (LHC) will be the most powerful particle accelerator around when, according to the plans, it will start operating in the year 2007. Each of its two 7-TeV proton beams will consist of 2808 bunches and each bunch will contain about 100 billion protons, for a total energy of 362 megajoules, enough to melt 500 kg of copper. What if one of these full-power beams were to accidentally strike a solid surface, such as a beam pipe or a magnet?



To study this possibility, scientists have now simulated the material damage the beam would cause. (In the case of an actual emergency, the beam is extracted and led to a special beam dump.) The computer study showed, first of all, that the proton beam could penetrate as much as 30 m of solid copper, the equivalent of two of LHC's giant superconducting magnets. It is also indicated that the beam penetrating through a solid material would not merely bore a hole but would create a potent plasma with a high density (10 percent of solid density) and low temperature (about 10 eV).

Such plasmas are known as strongly coupled plasmas. One way of studying such plasmas would therefore be to deliberately send the LHC beam into a solid target to directly induce states of high-energy-density (HED) in matter, without using shock compression. This is a novel technique and could be potentially a very efficient method to study this venerable subject. (Tahir et al., *Phys. Rev. Lett*. 94, 135004, 2005)

NICKEL-78, THE MOST NEUTRON-RICH OF THE DOUBLY-MAGIC NUCLEI

Nickel-78, the most neutron-rich of the doubly-magic nuclei, has had its lifetime measured for the first time, which will help us better understand how heavy elements are made.

Physicists believe gold and other heavy elements (beyond iron) were built from lighter atoms inside star explosions billions of years ago. In the "r-process" (r standing for rapid) unfolding inside the explosion, a succession of nuclei bulk up on the many available neutrons.

This evolutionary buildup is nicely captured in a movie simulation showing all the species in the chart of the nuclides being made one after the other. In some models the buildup can slow down at certain strategic bottlenecks. Nickel-78 is one such roadblock. This is because Ni-78 is a "doubly magic" nucleus. It has both closed neutron and proton shells; it is "noble" in a nuclear sense in the way that a noble gas atom is noble in the chemical sense owing to its completely filled electron shell.

This crucial nuclide is very rare and hard to make artificially. Nevertheless, scientists at the National Superconducting Cyclotron (NCSL) at Michigan State University have now culled 11 specimens of Ni-78 from among billions of high-energy collision events recorded. In effect, the NCSL is a factory for reproducing supernova conditions here on Earth. Hendrik Schatz, speaking at the April APS meeting in Tampa, reported that from the available Ni-78 decays recorded, a lifetime of 110 milliseconds could be deduced.

This is some 4 times shorter than previous theoretical estimates, meaning that the bottleneck nucleus lived shorter than was thought, which in turn means that the obstacle to making heavier elements was that much less. So far the exact conditions and site for the r-process are still unknown. With the new measurement model conditions have to be readjusted to produce the observed amounts of precious metals in the universe. This will provide a better idea of what to look for when searching for the site of the r-process. (See also Hosmer et al., *Phys. Rev. Lett*. 94, 112501, 2005)

THE FIRST DIRECT MEASUREMENT OF RECOIL MOMENTUM

The first direct measurement of recoil momentum for single atoms struck by light in an absorptive medium has been made by Gretchen Campbell, Dave Pritchard, Wolfgang Ketterle and their colleagues at MIT. Photons do not possess mass, but a beam of light does carry momentum. In general, when light strikes a mirror, the mirror will recoil ever so slightly, and this recoil has previously been measured. But what about a single photon striking a single atom in a dilute gas?

The momentum of a photon equals h/lambda, where h is Planck's constant and lambda is the wavelength of the light in vacuum. In a dispersive medium, the index of refraction for the medium, n, comes into play: an object absorbing the photon will recoil with a momentum equal to nh/lambda. This is what has been measured for the first time on an atomic basis.

The MIT team used laser beams sent into a dilute gas; a beat note between recoiling atoms and atoms at rest provided the momentum measurement of selected atoms. The fact that the recoil momentum should be proportional to the index of refraction came as something of a surprise to the experimenters. You might expect that in isolated encounters, when an individual atom absorbs a single photon, that the recoil of the atom should not depend on n. That's because the atoms in the sample–in this case a Bose-Einstein condensate of Rb atoms—is extremely dilute, so dilute that each atom essentially resides in a vacuum.

Nevertheless, the interaction of the light with all the atoms has to be taken into account, even if the specific interaction being measured, in effect, is that of single atoms. The atoms "sense" the presence of the others and act collectively, and the extra factor, the index of refraction, is applicable after all. Ketterle believes that this new insight about what happens when light penetrates a dispersive medium provides an important correction for high-precision measurements using cold atoms. (Campbell et al., *Phys. Rev. Lett*. 94, 170403, 2005)

LIGHT MAY ARISE FROM TINY RELATIVITY VIOLATIONS

Light may arise from tiny relativity violations, according to a new theory. Speaking at the meeting of the Division of Atomic, Molecular, and Optical Physics in Nebraska in May, Alan Kostelecky of Indiana University described how light might exist as a result of breaking Lorentz symmetry. In Lorentz symmetry, the laws of physics stay the same even when you change the orientation of a physical system (such as a barbell-shaped molecule) or alter its velocity.

Broken Lorentz symmetry would give spacetime a preferred direction. In its simplest form, broken Lorentz symmetry could be visualized as a field of vectors existing everywhere in the universe.

In such a picture, objects might behave slightly differently depending upon their orientation with respect to the vectors. In a recent paper, the authors propose that the very existence of light is made possible through a vector field arising from broken Lorentz symmetry. In this picture, light is a shimmering of the vector field analogous to a wave blowing through a field of grain.

The researchers have shown that this picture would hold in empty space as well as in the presence of gravity, which is often ignored in conventional theories of light. This theory is in contrast to the conventional view of light, which arises in a space without a preferred direction and as a result of underlying symmetries in particles and force fields. Kostelecky says that the new theory can be tested by looking for minute changes in the way light interacts with matter as the earth rotates (and changes its orientation with respect to the putative vector field). (Bluhm and Kostelecky, *Physical Review D*, 71, 065008, 2005)

NEW SPINTRONIC SPEED RECORD

Spintronics is the science devoted to gaining greater control over digital information processing by exploiting electron spin along with electron charge in microcircuits. One drawback to implementing a scheme of magnetic-based memory cells for computers has been the relatively slower speed of spin transistors. Hans Schumacher of the Physikalisch-Technische Bundesanstalt, Braunscheig, Germany, has now devised the fastest-yet magnetic version of a random access memory (MRAM) cell, one that switches at a rate of 2 GHz, as good as or better than the fastest non-magnetic semiconductor memories.

The MRAM architecture is a sandwich, consisting of two magnetic layers, with a tunneling layer in between. When the magnetic layers are aligned (their spin orientation is the same) resistance in the cell is low; when they are counter-aligned resistance is high. These two conditions establish the binary 1 or 0 states. The speed of writing or reading data to and from the cells has, for MRAMs, been limited to cycle times of 100 MHz by magnetic excitations in the layers. This problem has been overcome, according to Hans Schumacher, through a novel approach referred to as ballistic bit addressing.

In the case of the new MRAM architecture, the influence of magnetic excitations is eliminated through the use of very short (500 picosecond) current pulses for carrying out the write operation. The 2-GHz switching speed (the rate at which writing can be accomplished) is faster than static RAM (or SRAM) memories, currently the fastest memories, can accomplish. Furthermore, the magnetic memories are non-volatile, which means that the status of the memory does not disappear if the computer is shut down. (Schumacher, *Appl. Phys. Lett.* 87, 042504, 2005, *J. Appl. Phys.* 98, 033910, 2005)

A NEW KIND OF NANOPHOTONIC WAVEGUIDE

A new kind of nanophotonic waveguide has been created at MIT, overcoming several long-standing design obstacles. The device might lead to single-photon, broadband and more compact optical transistors, switches, memories, and time-delay devices needed for optical computing and telecommunications.

If photonics is to keep up with electronics in the effort to produce smaller, faster, less-power-hungry circuitry, then photon manipulation will have to be carried out over scales of space, time, and energy hundreds or thousands of times smaller than is possible now. One or two of these parameters (space, time, energy) at a time have been reduced, but until now it has been hard to achieve all three simultaneously. John Joannopoulos and his MIT colleagues have succeeded in the following way. To process a photonic signal, they encrypt it into light waves supported on the interface between a metal substrate and a layer of insulating material. These waves, called surface plasmons, can have a propagation wavelength much smaller than the free-space optical wavelength. This achieves one of the desired reductions: with a shorter wavelength the spatial dimension of the device can be smaller.

Furthermore, a subwavelength plasmon is also a very slow electromagnetic wave. Such a slower-moving wave spends more time "feeling" the nonlinear properties of the device materials, and is therefore typified by a lower device-operational-energy scale, thus achieving another of the desired reductions. Finally, by stacking up several insulator layers, the slow plasmon waves occupy a surprisingly large frequency bandwidth. Since the superposition of waves at a variety of frequencies can add up to a pulse that is very short in the time domain, the third of the desired scale reductions is thereby achieved.

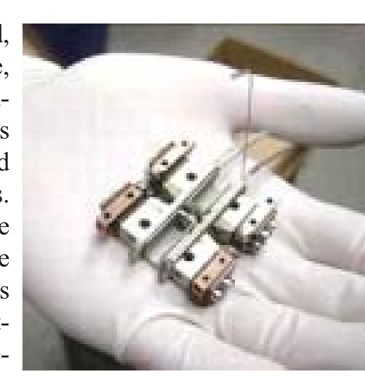
Reducing energy loss is another virtue of the MIT device. The plasmons are guided around on the photonic chip by corrugations on the nano-scale. In plasmonic devices the corrugations have usually been in the metal layer; this has always led to intractable propagation losses. However, in the MIT device they reside in the insulator layer; this, it turns out, allows for a drastic reduction of the losses by cooling. (Karalis et al., *Phys. Rev. Lett*. 95, 063901, 2005)

ROOM-TEMPERATURE ICE IN ELECTRIC FIELDS

Room-temperature ice is possible if the water molecules are submitted to a high enough electric field. Some physicists had predicted that water could be coaxed into freezing at fields around 109 V/m. The fields are thought to trigger the formation of ordered hydrogen bonding needed for crystallization. Now, for the first time, such freezing has been observed, in the lab of Heon Kang at Seoul National University in Korea, at room temperature and at a much lower field than was expected, only 106 V/m. Exploring a new freezing mechanism should lead to additional insights about ice formation in various natural settings, Kang believes.

The field-assisted room-temperature freezing took place in cramped quarters: the water molecules were constrained to the essentially 2-dimensional enclosure between a gold substrate and the gold tip of a scanning tunneling microscope (STM). Nevertheless, the experimental conditions in this case, modest electric field and narrow spatial gap, might occur in nature. Fields of the size of 106 V/m, for example, are thought to exist in thunderclouds, in some tiny rock crevices, and in certain nanometer electrical devices. (Choi et al., *Phys. Rev. Lett*. 95, 085701, 2005)

BEC IN A CIRCULAR WAVEGUIDE



Bose Einstein condensates (BECs), in which trapped, chilled atoms fall into a single corporate quantum state, have been achieved for several elements of the periodic table and in a variety of trap geometries. Physicists at UC Berkeley have now, for the first time, produced a BEC in a ring-shaped trap about 1 millimeter across. By using an extra magnetic field, in addition to those used to maintain the atoms in the trap to start with, the whole trap can be "tilted," so as to accelerate the atoms up to velocities of about 50-150 mm/sec (or equivalently to energies of about 100 pico-electron-volts per nucleon, as compared to the TeV energies sought for particle physics). After this initial "launch" phase, the atoms are allowed to drift around the ring; they do this not in clumps (as you would have with particles in a colliding-beam storage accelerator) but in a continuously expanding stream. However, starting from the BEC state, the atoms are more like coherent atom waves smeared out around the ring; they move ballistically and without emitting synchrotron radiation. According to Dan Stamper-Kurn, potential applications for BEC rings would become possible if parts of the circulating condensate could be made to interfere with other parts. From such an interferometer one could devise gyroscopes or high-precision rotation sensors. Other possible realms of study include quantized circulation, fluid analogues of general relativity, and fluid analogues of SQUID detectors and other superconducting devices. (Gupta et al., *Phys. Rev. Lett.* 95, 143201, 2005)

MAGNETIC BURNING

A new experiment suggests that the fast flipping of the magnetic orientation of some molecules in a solid sample resembles the propagation of a flame front through a material being burned, and that the "magnetic burning" process can be used to study flammable substances without actually having flames present. In a chemical fire–say, the burning of the pages of a book–the flame front marks a dividing point: ahead of the front is intact unburned material, while behind the front is ash, the state of material that has been oxidized in the combustion process. Now, consider the magnetic equivalent as studied by a collaboration of scientists from CUNY-City College, CUNY-Lehman College, the Weizmann Institute, and the University of Florida. A crystal of manganese12-acetate (Mn12-ac) molecules, each with a net spin of 10 units, is quite susceptible to magnetic influence. Turning on a strong external magnetic field opposed to the prevailing magnetic orientation of the crystal can cause a sudden reversal of spins of the molecules. The reversal propagates along a front through the crystal (which can be thought of as a stack of nanomagnets) just as a flame moves through a solid in the case of a conventional combustion. In the magnetic case, much heat will be generated as the spins get flipped (the heat energy being equal to the difference in energy of the before and after spin states), but there will be no destructive burning. The "ash" consists of the molecules in their new spin state. In summary, magnetic burning in molecular magnets has several of the qualities of regular burning (a flame front and combustion) but not the destructiveness. Myriam Sarachik says that magnetic burning might offer a more controlled way of learning how to control and channel flame propagation. (Suzuki et al., *Phys. Rev. Lett*. 95, 147201, 2005)

WHY DO WE RESIDE IN A THREE-DIMENSIONAL UNIVERSE?

Andreas Karch (University of Washington) and Lisa Randall (Harvard) propose to explain why we live in three dimensions and not some other number. Currently, the popular string theory of matter holds that our universe is actually ten-dimensional, including, first of all, the dimension of time, then the three "large" dimensions we perceive as "space," plus six more dimensions that are difficult to see, perhaps because they are hidden in some way. There is reason to believe, therefore, that our common 3D space is but a portion of some membrane or "brane" within a much more complicated higher-dimensional reality. Specifically, Karch and Randall address themselves to the behavior of three-dimensional force laws, including the force of gravity. Having several dimensions rolled up is one way to explain why gravity is so weak.

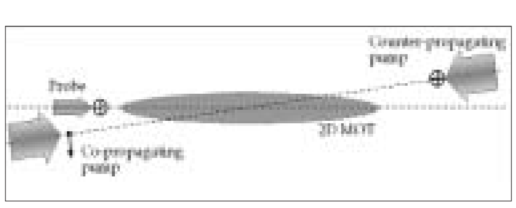
Another view, pioneered by Randall and Raman Sundrum, holds that if gravity is localized on a 3D defect in the larger multi-dimensional universe and if spacetime is sufficiently warped, then the other spatial dimensions might be large after all. But why is our "local gravity" apparently a 3D defect in a 10D universe? Why not a 4D defect or some other dimensionality?

In the present paper, Karch and Randall show that the cosmic evolution of the 10D universe, involving a steady dilution of matter, results in spacetime being populated chiefly by 3D and 7D branes. Several versions of string theories require the existence of 3D and 7D branes; indeed, the particles that constitute matter–such as quarks and electrons–can be considered open strings with one end planted on a 3D brane and the other end planted on a 7D brane. (Karch and Randall, *Phys. Rev. Lett*. 95, 161601, 2005)

NUCLEAR SEISMOLOGY

Physicists at the GSI lab in Darmstadt, Germany, have discovered a new excited nuclear state, one in which a tide of neutrons swells away from the rest of the nucleus. Ordinarily, in its unexcited state, a typical atomic nucleus consists of a number of constituent neutrons and protons bobbing around inside a roughly spherical shape. However, if struck by a projectile from outside, such as a beam particle supplied by an accelerator, the nucleus can be set to spinning, or it might distend. In one kind of excited mode called a dipole resonance, the protons can move slightly in one direction while the neutrons go the other way. In another type of excitation, a nucleus might consist of a stable core blob of nucleons surrounded by a surplus complement of one or two neutrons, which constitute a sort of halo around the core. In the new GSI experiment, yet another nuclear mode has been observed. The nuclei used, two isotopes of tin, are the most neutron-rich among the heavier nuclei that can be produced at this time. Sn-130 and Sn-132 are so top-heavy with neutrons that they are quite unstable and must be made artificially in the lab. At GSI this is done by shooting a uranium beam at a beryllium target. The U-238 nuclei, agitated by the collision, eventually fission in flight, creating a swarm of more than 1,000 types of daughter nuclei, from which the desired tin isotopes can be extracted for study. The tin nuclei are excited when they pass through a secondary target, made of lead. The excited tin states later disintegrate; the debris coming out allows the researchers to reconstruct the turbulent nature of the tin nuclei. The dipole resonance was seen, as expected, but also a new resonance: an excess of neutrons pushing off from the core nucleus. Furthermore, the neutron resonance appears at a lower excitation energy than does the dipole resonance. Team leader Hans Emling says that there was some previous evidence for the existence for the neutron mode in work with lighter nuclei, but not the actual oscillation observed in the present work. (Adrich et al., *Phys. Rev. Lett*. 95, 132501, 2005)

GUIDED SLOW LIGHT



Guided, slow light in an ultracold medium has been demonstrated by Mukund Vengalattore and Mara Prentiss at Harvard.

Slowing light pulses in a sample of atoms had been accomplished before by sending light pulses into a highly dispersive medium–that is, a medium in which the index of refraction varies greatly with frequency. Previously, this dispersive quality had come about by tailoring the internal states of the atoms in the medium. In the present Harvard experiment, by contrast, the dispersive qualities come about by tailoring the external qualities of the atoms, namely their motion inside an elongated magnetic trap.

In the lab setup, two pump laser beams can be aimed at the atoms in the trap; depending on the frequency and direction of the pump light, the atomic cloud (at a temperature of about 10 micro-Kelvin) can be made more or less dispersive in a process called recoil-induced resonance, or RIR. If now a separate probe laser beam is sent along the atom trap central axis, it can be slowed by varying degrees by adjusting the pump laser beam. Furthermore, the probe beam can be amplified or attenuated depending on the degree of dispersiveness in the atoms. This process can be used as a switch for light or as a waveguide.

According to Mukund (now working at UC Berkeley), slowing light with the recoil-induced resonance approach may be a great thing for nonlinear-optics research. Normally, nonlinear effects come into play only when the light intensities are quite high. But in the RIR approach, nonlinear effects arise more from the strong interaction of the two laser beams (pump and probe) and the fact that the slow light spends more time in the nonlinear medium (the trap full of atoms).

All of these effects are enhanced when the atoms are very cold. Moreover, because the slow light remains tightly focused over the length of the waveguide region, intensity remains high; it might be possible to study slowed single-photon light pulses, which could enhance the chances of making an all-optical transistor. The light in this setup has been slowed to speeds as low as 1500 m/sec but much slower speeds are expected when the atoms are chilled further. (Vengalattore and Prentiss, *Phys. Rev. Lett*. 95, 243601, 2005)

QUANTUM SOLVENT

Scientists at the Ruhr-Universität Bochum in Germany have performed high-precision, ultracold chemical studies of nitrogen oxide (NO) molecules by inserting them into droplets of liquid helium.

NO, *Science* magazine's "molecule of the year" for 1992, is important because of its role in atmospheric chemistry and in signal transduction in biology. A radical is a molecular entity (sometimes charged and sometimes neutral) which enters into chemical reactions as a unit. To sharpen our understanding of this important molecule and its reactions, it would be desirable to cool it down, the better to observe its complex spectra of quantum levels corresponding to various vibrational and rotational states.

In the new experiment, liquid helium is shot from a cold nozzle into vacuum. The resultant balls, each containing about 3,000 atoms, are allowed to fall into a pipe where NO molecules are lurking. The NO is totally enveloped and, within its superfluid-helium cocoon at a temperature of about 0.4 Kelvin, it spins freely. The helium acts provides a cold environment but does not interact chemically with the NO molecules. Because of this a high-resolution infrared spectrum of NO in fluids could be recorded for the first time.

NO has been observed before in the gas phase, but never before has such a high resolution spectrum be seen in the helium environment. (Haeften et al., *Phys. Rev. Lett*. 95, 215301, 2005)

MEASURING HIGHER-LEVEL QED

A new experiment at Livermore National Lab has made the best measurement yet of a complicated correction to the simplest quantum description of how atoms behave. Livermore researchers did this by measuring the Lamb shift, a subtle shifting of quantum energy levels, including a first measurement of "two-loop" contributions, in a plasma of highly charged uranium ions.

For hydrogen atoms, containing but a single electron and a proton for a nucleus, the Lamb shift can be measured to an accuracy of a few parts in a million, and theoretical and experimental values agree very well. One would like also to measure the Lamb shift (and hence test basic QED precepts) for other elements. One would like also to measure separately the contribution of higher-order contributions to the Lamb shift.

In hydrogen, two-loop and other higher contributions play a very small role in the Lamb shift. Furthermore, uncertainty in the size of the proton limits any effort to measure two-loop effects. This is not true for a uranium atom in which nearly all the electrons have been stripped away. With a much larger nucleus, the proton-size issue is much reduced, and the electric fields holding electrons inside the atom are a million times stronger (10^{17} volts per meter) than in hydrogen. Thus, QED can be tested under extreme conditions.

The Livermore physicists study uranium atoms that have been stripped of all but three electrons. These lithium-like uranium ions, held in a trap, are then carefully observed to search for the Lamb discrepancy from simple quantum predictions as to the frequencies of light emitted by the excited ions. In hydrogen atoms, the two-loop corrections constitute only a few parts per million, but in uranium atoms they contribute about one third of one percent of the Lamb shift. In this way, the Livermore team has measured this higher-level QED term for the first time, with an accuracy of about 10 percent. (Beiersdorfer et al., *Phys. Rev. Lett*. 95, 233003, 2005)

A TERA-ELECTRONVOLT GAMMA RAY ORIGINATING IN THE MILKY WAY

The most energetic parcels of electromagnetic radiation–Tera-electronvolt gamma rays–ever determined to have originated in the plane of our home galaxy were observed recently by the Milagro detector, located at high mountain elevations in New Mexico. The potent photons are believed to have been part of the debris spawned when even more energetic cosmic rays struck the matter-dense heart of the Milky Way.

Photons in the TeV range arrive at the Earth very rarely, not often enough to permit observation from a space-based gamma telescope. Therefore, terrestrial gamma observations are usually carried out by large-area-arrays attached to the ground.

Milagro, operated by scientists from nine institutions, records the arrival of energetic photons at Earth by observing the air shower of secondary particles generated when the gamma rays hit the atmosphere. These particles betray their presence by the light (Cerenkov radiation) emitted when the particles pass through a 6-million-gallon pond instrumented with photodetectors. This method of observation offers a rough ability to determine the direction of arrival.

For the Milagro experiment so far, 70,000 TeV photon events from within a region of the Milky Way plane were culled from an inventory of about 240 million TeV-level events seen so far seen from the same region. These numbers, says team member Roman Fleysher of New York University, are consistent with theoretical estimates for cosmic ray production.

And where do the cosmic rays get their 100-TeV-and-more energies? Ions in the interstellar medium, perhaps near a collapsed star or an active galactic nucleus (AGN), can get caught up by shock waves and accelerated to high energies. (Atkins et al., *Phys. Rev. Lett*. 95, 251103, 2005)

Undergrad Awards Promote Student Participation at DNP Meeting

Last September about 75 undergraduates were able to mix the pleasure of attending a nuclear physics conference with the business of hanging out on the beach in Hawaii.

The students were in Maui attending the 2005 Division of Nuclear Physics meeting as part of the Conference Experience for Undergraduates (CEU). Each year the CEU program brings between 70 and 90 undergraduates to the DNP meeting. The students, who have done research in nuclear physics, present their work at a special undergraduate poster session.

CEU draws applications from students around the country. These applications are reviewed by a committee, and about half receive travel and lodging awards. Funding for the CEU awards is provided by the NSF and DOE. Even those students who don't receive awards are often able to attend, with help from their advisors. For many of the students, the DNP meeting is the first professional conference they attend, and their first time presenting their research.

In September 2005 the DNP meeting was held in Maui as a joint meeting with the Japanese Physical Society [see *APS News*, January 2005]. In addition to the American students, 16 Japanese students attended. There was a good exchange between American and Japanese students, said CEU organizer Warren Rogers of Westmont College. "It was really a historic opportunity."

CEU is more than just getting the students to present their research, said Rogers. Each year the CEU includes several activities especially for undergrads, including two special nuclear physics seminars presented at an advanced undergraduate level. Other events for the students included a reception, an ice cream social, and a graduate school information session, at which representatives from several universities and laboratories met with the students to discuss graduate school opportunities.

The students are full participants in the meeting, and are encouraged to attend as many of the regular sessions as they can.

"I felt like I could go to any talk I wanted, and felt privileged to have that opportunity to be in the company of great research scientists," said Fatima Mahmood, a CEU participant from Union College. "I did attend several talks in the regular program. I enjoyed hearing about modern research in nuclear physics, and even when I couldn't understand a lot of the talks, I was glad to find certain terms and ideas were familiar to me through my own experience in research and from my studies in college."

Several 2005 CEU students said that the opportunity to present their work in the poster session was the most valuable part of the meeting.

"People were interested and asked interesting questions, so that was good," said Andrew Ratkiewicz of Indiana University at South Bend.

"It was very interesting and helpful to have other physicists looking at my work and ask me new questions. It definitely inspired me to further research these unexpected questions," said Laura Stiles of the University of Kansas.

"I had a lot of positive comments about my research. One group thought it was very impressive that I could get the project done in one summer, and another thought the ideas behind it were very interesting," said Daniel Passmore, a student at the University of Tennessee, Knoxville.

Scientists at the meeting have been very impressed with the students' research, said Rogers. "They are amazed at the quality of the undergraduate work. The students find out that their research is truly valued. I think that is very motivational for them."

"Numerous DNP colleagues have also expressed sincere appreciation for the energy and enthusiasm the students bring to the meeting, and several have reported that meeting the students and attending the CEU poster session is for them one of the highlights of the meeting," said Rogers.

Rogers began running the CEU program in 1998 after he noticed that few undergraduates attended the DNP meetings. Many undergrads had participated in research at their universities or during a summer program, but hadn't had the chance to present their work at a professional conference. Rogers also wanted to encourage greater retention of talented undergrads in the field of nuclear physics.

Photo credit: Warren Rogers

NSF Assistant Director Michael Turner (in red shirt) chats with CEU participants at an ice cream social during the DNP meeting in Maui.

Some of the 2005 CEU students say they plan to continue to study nuclear physics, while others have interests in different fields. They were certainly glad to have had the chance to attend the meeting.

"I can't believe what wonderful opportunities physics has opened up for me," said Mahmood.

Beverly Lau, a CEU participant from Reed College said, "If becoming a nuclear physicist means a free trip to Maui once every five years –count me in!"

Rogers would like to encourage other APS units will try something similar to CEU. "Some APS units do have some undergrad involvement, but nothing on this scale," said Rogers. "I've hoped that other divisions would become interested in doing something like this. The success (of CEU) within the nuclear physics community can't be overstated."

UC CONTINUED FROM PAGE 1

Many Los Alamos employees were generally pleased that UC won the contract, though not overly optimistic, said Holian. Morale has been extremely low at LANL recently, he said.

Rhon Keinig, who retired recently after 25 years at Los Alamos said, "The people in upper management were totally incompetent. I thought people were really destroying the science base of the laboratory."

The new director at Los Alamos will be Michael Anastasio, who is the current director of Lawrence Livermore National Laboratory. "I've heard good things about the new director," said Holian. "People seem to like him at Livermore."

Lawrence Livermore Lab will seek a new director. Livermore is currently managed by the University of California, but the contract expires in 2007, and the DOE is planning to put that management contract out to a competitive bid.

There has been a lot of anxiety at Los Alamos recently about the new contractor. Los Alamos employees are waiting for more detailed information on how the new management will operate, what changes will be made, and how new pension and benefits plans will work. Holian says he does not expect very significant changes in the way the lab is run, and he hopes that the next couple of years will be relatively quiet at the lab, with no major upheavals. Keinig said he expects there will be some chaos while restructuring takes place.

Some Los Alamos scientists worry that emphasis at the lab may now shift away from science, towards weapons engineering and manufacturing. "I believe there will be increasing emphasis on plutonium pit manufacturing rather than scientific things," said Holian. He and Keinig both said they believe good science will continue to be done in some divisions of the lab.

The lab could perform very necessary science if it focuses more on energy problems, said Holian. "We are an energy lab. It might be time to focus on energy problems," he said. "The lab can do a great deal of service to the country."

"Nuclear weapons is not a growth industry. (At least I hope not)," said Keinig. "I hope they find a better balance in the programmatic work. Without the nuclear program, Los Alamos would not exist. But that doesn't mean that that should define the lab. A better balance between weapons work, pure science, and threat reduction needs to be emplaced at LANL for it to again become a true national treasure."

FEMALE FRIENDLY CONTINUED FROM PAGE 4

at 107 graduate institutions. Some give very little information, some give much more. Neither APS nor CSWP assumes any responsibility for the accuracy or the timeliness of the information presented. Still, this should be a valuable tool for prospective students.

The results can be found at http://cswp.catlla.com/results.php

The CSWP urges all readers to inform their seniors about this website, and also urges those thinking about instituting family leave/family health insurance policies to peruse the database for information about the policies of other institutions. Finally, any department chairs who wish to add their departments (or change their existing entry), should contact me at mtsher@wm.edu and I'll supply the URL for entering data.

Marc Sher is Professor of Physics and Director of Graduate Admissions, College of William and Mary

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ENDOWED LECTURES CONTINUED FROM PAGE 1

International Linear Collider and of international collaboration on big scientific projects. He currently serves as the international representative on the APS Council. He will give a plenary talk at the April Meeting on "Physics Prospects and International Aspects of ILC." Wagner was nominated for the Beller Lectureship by the Division of Particles and Beams and the Division of Particles and Fields.

Awarded occasionally in recent years, the Beller and Marshak Lectureships will now become annual events administered by CISA. Each year, CISA will invite the APS Divisions, Topical Groups, and Forums to submit nominations of candidates for the lectureships. An announcement of the call for 2007 online nominations will appear soon.

"This is an outstanding opportunity for the units and CISA to work together ," said Amy Flatten, APS Director of International Affairs. "International activities cut across all aspects of the Society, and CISA is eager to collaborate with all APS units to award these annual lectureships."

INSIDE THE BELTWAY CONTINUED FROM PAGE 2

secondary science education and, for the last twenty years, a shrinking federal commitment to physical science research. Without the fount of discoveries that basic research produces, American innovation soon will be just a chapter in American history books.

Don't get me wrong: we haven't quite lost the battle. But just because we haven't fallen flat on our faces yet, doesn't mean we aren't about to get our bottoms booted. Check out the R&D benchmarks of the United States and of our competitors. They're more than a little scary, at least if you worry about your children's future.

Sadly that message hasn't yet resonated with the macho culture of the current administration. It's one thing if the messengers were only liberal academics who still sport "Kerry for President" bumper stickers on their Volvos. But when they are some of the titans of corporate America–the likes of Norm Augustine, retired Chairman and CEO of Lockheed-Martin; Craig Barrett, Chairman of the Board of Intel; Ron Sugar, CEO of Northrup-Grumman; Lee Raymond, Chairman of the Board and CEO of Exxon Mobil–you'd think the President would instantly pick up the phone and invite them in. He might have wanted to, but for the better part of a year his gatekeepers didn't.

Finally, in December, heavy hitters in the Administration–only one notch below the President and including his closest advisors –opened their doors. They might not have liked what they heard, but they listened. Give them credit for that. Time will tell whether they will give their boss the bad news and begin to correct two decades of "bipartisan lack of vision," as Burton Richter, Nobel Laureate and former SLAC Director, is fond of describing the budgetary shambles.

It will require more than a robust presidential research budget request or an Energy Secretary who has made science his number one priority, with at least some of the dollars to back up his rhetoric. It will require presidential fortitude and jawboning. The reason is plain.

Conservatives in Congress will press hard for more tax cuts and reductions in spending. And unless the Administration makes science and competitiveness a central theme for Fiscal Year 2007, the coming months will seem like an agonizing slo-mo replay of the Fiscal Year 2006 disaster, when appropriators, usually sympathetic to science, fumed that they had finally had their fill of trying to clean up the mess the White House was continuing to create.

Add to this the dynamics of a hard-fought election year, in which partisan politics will play a dominant role, and science could vanish from the agenda of both parties, unless advocates weigh in heavily.

One third of the Senate seats and all of the House seats are up for grabs. And Democrats, savoring the allegations of illegal, unethical or simply improper behavior that have racked the Republican leadership, sense the possibility of reclaiming control of Congress in November. Without a doubt, nastiness and negativism will dominate the campaign.

But as the public inevitably tires of partisan bashing, a window of opportunity will open for science: it could become a compelling issue that both sides feature as a positive counterpart to the dark sides of their campaigns. If that happens, the nation would benefit enormously. The House Democrats have embraced the innovation theme. It's time for the Republicans to take up the challenge. It wouldn't hurt for them to hear from some of their constituents, and the sooner the better.

The Back Page

Changing the Climate… of Public Opinion

By Spencer Weart

I took this photo last August, as a tourist on Baffin Island in the Arctic. Looking down the glacier, the nearby ridge of rubble is a moraine, most likely dropped since the late 19th century. The glacier is continuing to melt back, like many around the world. Our group also saw less pack ice than expected, and the bird-watchers were disappointed when they couldn't check off some high-latitude species. Such experiences are now often in the news. Physicists may find their students or nonscientific friends asking questions–or you could raise the issue yourself. People wonder, is global warming really a problem? How do we know? Can we do anything about it? Is it urgent?

One way to answer such questions would be to invoke the authority of science. Many people are not aware that the scientific community has finally reached a consensus on the risk of climate change. Public awareness has been held back by a belief that acknowledging the risk would lead to government regulation, and thus the question became politicized. Weird but true: if someone holds strong opinions about the role of government, you can usually guess from those opinions what they think about plain scientific assertions on climate change. A public relations campaign, amply funded by fossil-fuel corporations and their allies, has deliberately fostered doubt. The industrial coalition publicized the opinions of a few people who cherry-picked items from larger data sets to build unscientific counter-arguments. (For such biased selection see Michael Crichton's latest thriller, *State of Fear*.) Meanwhile a few respectable scientists took on the role, appropriate in science, of playing devil's advocate–raising counter-arguments that spurred their colleagues to more rigorous studies (which dismissed the objections). The bickering over details allowed the American media to offer a supposedly "evenhanded" view, in which any scientist explaining the risk of warming was "balanced" by one of the few skeptics.

Half a century ago, nearly all scientists thought greenhouse warming was scarcely likely to be a problem. It took decades of accumulating evidence, with many hard-fought debates, to convince them they were wrong. Panels of scientists convened on climate change hundreds of times in many countries. As scientists, most of the panelists were professional skeptics. Yet since the late 1970s essentially every such panel has concluded that warming could become a bad problem someday. In the present century, every respectable panel has concluded that it probably will be a severe problem, and soon.

Some people suspect such panels are just an old-boy-and-girl network looking out for its own research funds. History helps counter that suspicion, for the origins of the present consensus are revealing. The Reagan administration believed that any self-appointed group of scientists would issue alarmist, hyper-environmentalist statements. They forestalled that by promoting a complex international advisory structure, led by people appointed by governments rather than by the scientific community. To further impede any statements that might push toward government regulation, the advisory group's conclusions would have to be consensual –the unanimous findings of representatives of all the world's governments. The result is the Intergovernmental Panel on Climate Change (IPCC). Surprisingly, the process produced useful advice. Relentlessly confronted with the evidence and arguments of their colleagues, even the science representatives of oil-rich states eventually agreed that the world is very likely warming at an unprecedented rate, and that the most likely cause is the buildup of greenhouse gases due to human activities.

The key here is a simple matter: in such a complex issue we cannot have certainty, and we don't claim it. The scientific community, as represented by the IPCC, plus many of the world's leading science academies and societies, only says that serious global warming is more likely than not. After all, hardly anything that relates to economic or social policy is certain. The evidence that we face a serious climate risk is now stronger than the kind of evidence we normally use in deciding tax policy, investments in costly highways, and the like.

How do we know the whole world is really warming up? One quick and vivid answer is the unprecedented melting back of glaciers, exposing archeological finds like the Alpine "iceman" that had been frozen for thousands of years. The atmospheric temperature fluctuates hour by hour, so it seems a monumental task to arrive at an average global temperature and say it has gotten a few tenths of a degree warmer. It has indeed been a monumental task, the work of thousands of scientists. Most of the heat energy added by the greenhouse effect isn't stored in the wispy and inconstant atmosphere anyway. It mainly winds up in the oceans. The heat energy seeps down gradually through the seawater, a very poor conductor, or is carried down by slow-moving currents. The latest analysis of the temperature structure in all the main ocean basins shows a strong and rapid warming in recent decades. Moreover, the geographic and depth patterns closely match the predictions that computer models make for greenhouse gas warming. The patterns cannot be matched to any other cause, such as variations in the Sun.

How do we know the computer models are any good? Never before in human history have nations been asked to stake major policies on such complex scientific calculations. I find it a hopeful sign, a big advance in rationality, that all governments now take this seriously. After all, as some say, "How can scientists predict the climate a century ahead when they can't predict weather a year ahead?"

The short answer is that the problems are different, since a season's climate is the average of all the season's weather. Computers can predict the weather a couple of days ahead pretty well, if far from perfectly, and predicting climate a century ahead is at about the same stage.

Photo of glacier on Baffin Island

Photo credit: Spencer Weart

A longer answer would start by noting what an impressive achievement it is that computers can make models that look much like Earth's actual climate. It's a hugely complicated system, but models get the winds and sea currents and rain and snow in all the right places. More impressive still, the models can track all this through the seasons, as if the same model worked for two radically different planets: Summer and Winter. But perhaps the most impressive is the natural experiment conducted in 1991. That was when the volcano Pinatubo blew a cloud the size of Iowa into the stratosphere. A relatively simple model predicted in advance the temporary global cooling this would produce. Current models are even better at reproducing the event's consequences.

The modelers can get these results only by adjusting a lot of parameters that are poorly known, such as the numbers in the model that tell how clouds are formed. What if they're unconsciously fudged, or just wrong? The shortest answer is yes, they might be wrong. If they're wrong one way, we might have no serious change. But if they're wrong the other way, we will have catastrophic climate change. Amidst this uncertainty we can only say, again, that a damaging change is more likely than not.

If pressed for a more complete answer, I would tell about the study so big it needs more computer power than any group commands. So it uses distributed computing. Your PC can join the effort in its idle time: go to http://ClimatePrediction.net. You'll get a set of parameters for a simplified model, and run it to see if it will reproduce the 20th century's climate (one of my runs ended up with no clouds, other people had all the water precipitate as ice at the poles, etc.). Once you get a set of parameters that gives a fair approximation to the known past climate, you can double the carbon dioxide in the atmosphere and run it again. The results from thousands of runs with different parameter sets are revealing. A few sets of parameters give no warming. A larger number of sets produces shockingly large warming, up to 11°C by the end of the century. Most of the parameter sets, however, get climates that group near the results from single runs of the most advanced models, showing a warming somewhere in the range 1-5°C. That confirms what modelers have found ever since the 1970s: if you can make any kind of model that gets the past climate roughly right, it takes serious fudging to get it not to warm up when you add greenhouse gases. (For explanations and updates on many other questions see http://www.RealClimate.org.)

But is there anything we can do? Here we are impeded by a viewpoint, supported by interests that are afraid to change their business models or their political models, which insists that it is impossible to reverse the rise of greenhouse gases without wrecking our economy. Yet any physicist can see that people can take many steps that actually save them money and benefit the overall economy. For instance, we can use more efficient light bulbs. Beyond that are collective actions that will be beneficial in many ways, such as reducing the inefficiencies in cars that not only add to global warming but make many countries spend huge sums to get foreign oil. For a start, why not stop subsidizing global warming? Currently tens of billions of taxpayer dollars are wasted in open and hidden subsidies of fossil fuel industries and other contributors to greenhouse emissions. (Many groups are working on this; one starting point is the Pew Center for Climate Change, http://www.pewclimate.org/.)

What we need is a change in the climate–of opinion. Americans in particular ought to make their nation not the world's laggard, but its leader in addressing the problem. We should be challenging other nations to match us in staving off global warming. Many tools are already at hand and many more can be developed. If the climate does turn bad, we may have to use most of them. The necessary large change in public attitudes is certainly possible, for leaders of many corporations, state and local governments, and others have noticed the danger and are starting to take action on their own.

How urgent is it? We don't know, and therefore it's urgent. Come again? Well, if you don't know whether your house is on fire, but there's a good chance it might be, that's urgent. Even if there's only a small chance that it will ever catch fire, you're willing to spend a significant fraction of your wealth on insurance. For climate, one mechanism that suggests we are at urgent risk can be explained to almost anyone able to grasp elementary physics. As cold regions grow warmer, the bright snow and ice cover that reflect sunlight back into space are retreating earlier in the spring, exposing dark soil and open water, which absorb sunlight, which leads to further warming, and so on. That's why global warming is showing up first in the Arctic: an effect scientists have predicted since the 19th century. You might also mention a second risk, recognized more recently. The world's vast expanses of frozen tundra store fossil carbon, and as the permafrost melts, methane bubbles out; methane is an even more potent greenhouse gas than carbon dioxide, and leads to further warming. Geoscientists have identified several other mechanisms that might possibly push the climate abruptly into a dangerous state. Possibly we are approaching a tipping point.

We can probably arrest the process before it becomes irreversible. The cost may be no worse than we spend on other kinds of insurance. But not if we keep putting off effective action. Every scientist has a public responsibility to be well enough informed about climate change to answer the questions that we may be asked. And we all have a responsibility to engage in the effort to change the climate of opinion, and quickly, on what might be the most crucial issue of our times. Just possibly might. Actually, more likely than not.

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Further Reading:

Weart, Spencer R., 2003. The Discovery of Global Warming. Cambridge, MA: Harvard University Press; more extensive and updated text at http://www.aip.org/history/climate.