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NMD, National Security Issues Featured at 2001 April Meeting in Washington

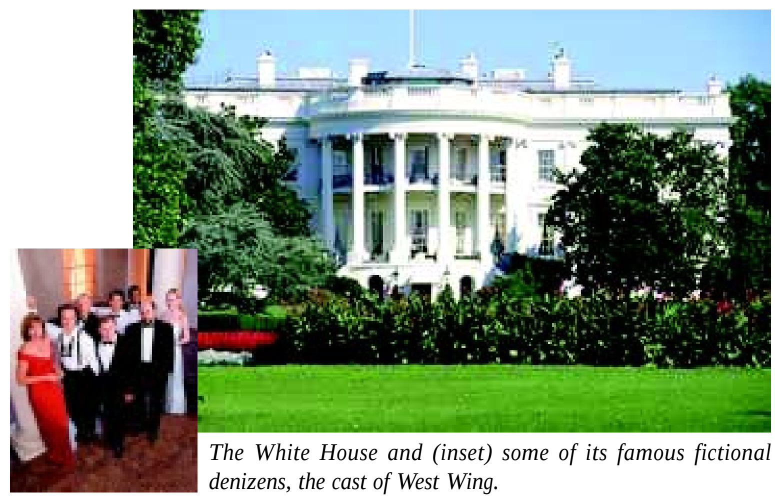
Attendees of the 2001 APS April Meeting, which returns to Washington, DC, this year, should arrive just in time to catch the last of the cherry blossom season in between scheduled sessions and special events. The conference will run April 28 through May 1, and will feature the latest results in nuclear physics, astrophysics, chemical physics, particles and fields, computational physics, plasma physics, the physics of beams, and physics history, among other subdisciplines. The April Meeting will also be noteworthy for a number of sessions devoted to science policy issues, including national missile defense (NMD), balancing scientific freedom with national security interests, and climate change.

Along with the standard array of technical sessions, the meeting will feature three sessions of plenary lectures on a broad range of topics of general interest to the scientific community. Highlights include a talk on how the news media cover science by David Kestenbaum, a self-described "escaped physicist who is hiding out at National Public Radio," and a lecture on entangled photons for quantum information by the University of Illinois' Paul Kwiat. Other scheduled topics include imaging the cosmic background wave background, searching for extra dimensions, CP violation in B mesons, neutrino oscillations, and the amplification of atoms and light in Bose-Einstein condensates. For a complete list of plenary speakers and topics, see http://www.aps.org/meet/APR01/

Sessions A1, G1 and P1, Grand Central Ballroom North/ Central, Renaissance Hotel.

CP Violation, Muon G-2, RHIC Results, and Neutrinos

Among the many sessions devoted to the latest results in nuclear, particle and astrophysics and the physics of beams, will be:



The White House and (inset) some of its famous fictional denizens, the cast of West Wing.

Session C4 on B Physics and CP Violation, sponsored by the Division of Particles and Fields, will feature talks on the latest results from the B-factories. The results from Belle will be presented by Kay Kinoshita of the University of Cincinnati, while those from Babar will be reviewed by David Kirkby of Stanford.

Renaissance West A, Saturday at 2:30

Session C10 on Lepton Properties, also sponsored by DPF and also taking place Saturday at 2:30 (in Renaissance Room 3) will have four talks on various aspects of the recently announced measurement of the muons's magnetic moment, which conflicts at the

See APRIL MEETING *on page 6*

Phase I CPU Report to be Discussed at April Meeting

The first phase of a new National Research Council report of the Committee on the Physics of the Universe (CPU) will be the topic of discussion during a special Sunday evening session at the APS April Meeting in Washington, DC. The session is intended to begin the process of collecting input from the scientific community on some of the issues outlined in the draft report, and members of the CPU will be present to respond to questions and hear comments on the content of the report. There will also be time for open discussion of future projects to realize the science opportunities.

Chaired by Michael Turner of Fermilab and the University of Chicago, the CPU was established early last year. The Phase I report to be presented at the April Meeting summarizes the science and discusses the most timely opportunities in a rapidly developing and very active area of research, according to Turner.

The second phase of the committee's task is to evaluate and prioritize projects that address science at the intersection of physics and astronomy. The committee has also been asked to address the issue of inter-agency cooperation and possible barriers to it, since many of the projects in this interdisciplinary area will likely be funded by more than one agency.

Session M1, Grand Ballroom NC, Renaissance Hotel

For more information on the CPU study, see http://www.nas.edu/bpa/projects/cpu.

Peaceful Transfer of Power

Alan Chodos/APS

Outgoing APS President James S. Langer (left) hands the gavel to new President George H. Trilling at the start of the Executive Board meeting in February.

NAS Publishes Survey of "Physics in a New Era"

Ed. Note: This story was written for APS News by Jordan Raddick.

"There is an awful lot of exciting stuff going on in physics," said Thomas Appelquist of Yale University, chairperson of the committee that wrote "Physics in a New Era," a report just published by the National Academy of Sciences (NAS) as a decennial "State of Physics" address. The report profiles the frontiers of American physics research and outlines recommendations for physics policy. It is now available from NAS, and will be officially introduced at a press conference this month in Washington, DC.

The physics overview committee comprised of 14 physicists from around the country, who worked for two years to produce the report. "What we try to do with these reports is to identify and articulate the consensus of the community," said Donald Shapero, director of the Board of Physics and Astronomy at the NAS. The committee met with the heads of federal funding agencies, and sought advice from APS members. "We got a lot of substantive and thoughtful responses [from APS members]," Appelquist said. The committee reviewed physics research, and evaluated how physics has changed over the past ten years.

The report focused on four

See NAS SURVEY *on page 2*

AIP Report Finds Academic Jobs for Physicists Are On the Rise

The academic job market over the last two years is characterized by increases in the number of vacancies and retirements, with corresponding increases in the number of new hires and recruitments, according to the 2000 Academic Workforce Report, released recently by the American Institute of Physics (AIP). AIP's Division of Employment and Education Statistics has been tracking the academic workforce every two years since 1986. "A sizeable percentage of PhD physicists work in academia, and hence this sector is a good indicator of the health of the entire discipline," says Roman Czujko, who heads the AIP division and co-authored the 2000 report.

Among the report's most notable findings is that the turnover and retirement rates for physics faculty are on the rise; in fact, the retirement rate is currently higher than 3% for the first time (it never rose above 2.6% throughout the 1990s), and is expected to continue to increase slowly due to the increasing age of the physics faculty. Degree-granting physics departments in the US employed an estimated 8375 full-time equivalent physicists during the spring of 2000, but even with the higher retirement rate, there are fewer than 250 physics positions vacated due to retirement each year. Czujko speculates that part of the reason for this may be that faculty retirement "is often a multi-step process, with many members reducing their status to part-time for several years before finally retiring completely."

Turnover rates were also higher among tenured and tenure-track faculty during the 1999 academic year than in previous years. The report found that 388 faculty members left their tenure or tenure-track positions, for a total turnover rate of 7.3%. "To the extent that increases in turnover rates are caused by aging faculty, we may continue to see increasing turnover rates for several years," says Czujko.

As a result of higher retirement rates and job turnovers, the numbers of new hires and recruitments have also increased, the report concludes. In 2000, US physics departments hired an estimated 329 tenured and tenure-track faculty members, a substantial increase from the 1998 estimate of 264 tenured or tenure-track positions. The overall percentage of physics departments hiring for such positions increased as well, from about one-fourth in 1996 and 1998 to 35% in 2000. All

See AIP REPORT *on page 3*

HIGHLIGHTS

NAS Survey, *from page 1*

“frontiers” of physics research – quantum manipulation, complex systems, the structure of the universe, and fundamental symmetries. In particular, the report concluded that new tools and techniques have revolutionized astrophysics and cosmology. “We are in the middle of a golden age in that field,” Appelquist said.

However, one of the biggest changes in the way physics is done in the last ten years has come from the ease of electronic communication. “The Los Alamos archive and e-mail have speeded up scientific communication tremendously,” Shapero said. In February, Brookhaven National Laboratory announced new measurements of the muon magnetic moment. A few days later, two theoretical papers appeared on the Los Alamos archive – one from a senior theorist at Brookhaven, and one from a researcher in India. “That would have been inconceivable fifteen years ago,” Appelquist said. “It’s an astonishing globalization.”

The committee examined the role of physics in society and developed nine recommendations for physics policy in the next ten years. They recommend that federal physics funding, relative to GDP, should be increased to its early-1980s level, and that the US help lead international collaborations to build experimental facilities. They also recommend that more attention should be paid to physics education, from elementary to graduate school. “Undergraduate education is badly in need of revamping and improvement,” Appelquist said. The report recommends that graduate education should include the training of students for jobs in industry, which employs most PhD graduates today.

Thomas Appelquist

The report also concluded that physics will increasingly broaden its influence on other sciences, especially the life sciences. “We think that physics is likely to provide a lot to the biological sciences, neuroscience in particular,” Appelquist said. In the past, Shapero said, physics was viewed as a tool for life sciences, but now physicists are beginning to understand how collaboration with biologists can aid physics as well.

To order a copy of “Physics in a New Era,” e-mail the Board of Physics and Astronomy of the NAS at bpa@nas.edu.

MIT To Host First Conference on Image and Meaning in Science

Scientists from nearly every discipline will join animators, architects, film makers, graphic artists and others for a conference on image and meaning, to be held June 13-16 at the Massachusetts Institute of Technology (MIT). Conference participants will discuss and demonstrate the most advanced forms of visual expression from science, technical and nonscientific visual fields in both plenary sessions and more informal working sessions. Specific topics to be covered include exploring ways in which techniques developed for one discipline can be used in others; the role of science writers in adding information and meaning to an image; the psychology of perception; graphical representation of numerical data; and the border between image enhancement and falsification.

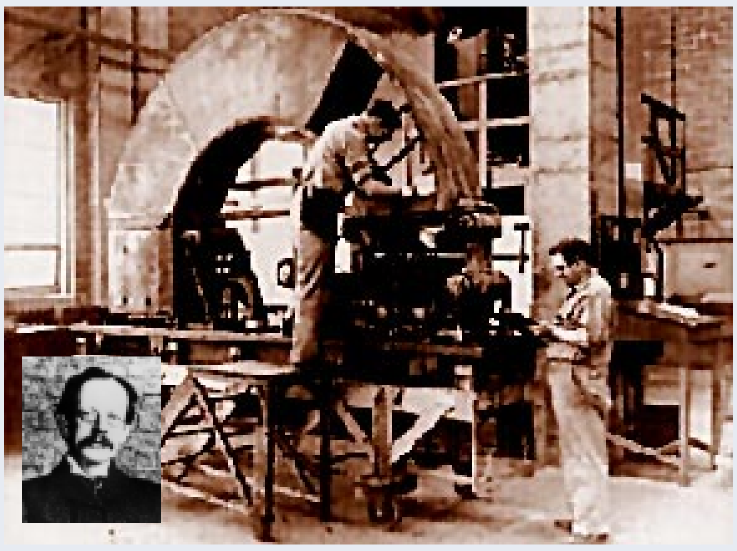
“As human beings, we assimilate the world chiefly through our sense of sight. Both the increasing complexity of science and the invention of new methods of visualization provide a remarkable opportunity to use the new visualization technologies to communicate science,” says Felice Frankel, an award-winning science photographer (see *APS News*, May 1999) who is co-organizing the NSF-funded conference. “But this communication will not be effective unless science communicators and science imagers learn more about one another, and develop more sophisticated ways to interact.”

Among the program highlights is a special Thursday evening on science as spectacle, with representations from Digital Domain, Industrial Light and Magic, and Sony Imageworks showcasing their latest technologies on how to present scientific information, followed by a panel discussion on what does and doesn’t work when film and television try to explain science. Friday evening will feature appearances by Alan Lightman, Roger Penrose, Susan Sontag and E.O. Wilson, in what is being touted as a “conversation” about how images in science have changed the way we view ourselves.

This Month in Physics History

April 1946: First Concept of Time-of-Flight Mass Spectrometer

Since its humble origins nearly 100 years ago, mass spectrometry has become a virtually ubiquitous research tool, with scores of scientific breakthroughs, including the discovery of isotopes, the exact determination of atomic weights, the characterization of elements, and characterization of molecular structure. In fact, it is arguably one of the most important types of complex instruments in many fields of science and industry for much of the 20th century, yet the technology is generally unknown among the educated public.



Part of the Calutron mass spectrometer first used for preparative MS; inset photo of J.J. Thomson.

Mass spectrometers are crucial for astronomical studies of our solar system. They are also key to the non-invasive international monitoring of nuclear facilities, and are becoming important tools in studies of surface phenomena. Commercially, mass spectrometry has long played a significant role in materials analysis and process monitoring in the petroleum, chemical and pharmaceutical industries, and are also used in the food processing and electronics industries. It is increasingly used in toxicology, drug abuse diagnosis and pollution monitoring, as well as for biological and biomedical uses.

A mass spectrometer is usually defined as any device that operates by a process used to produce a mass spectrum, and the instruments have appeared in ever-increasing variety of designs since their inception. Among these designs is the innovation known as time-of-flight mass spectrometry (TOFMS), a technique that determines the molecular weight of a substance by accelerating ions toward a detector. The time it takes to travel from the ion source to the detector is measured, then converted to mass with high accuracy. The greater the ratio of mass to charge, the slower the ion speeds toward the detector as it is accelerated.

The first mass spectrometer — originally called a parabola spectrograph — was constructed in 1912 by J.J. Thomson, best known for his discovery of the electron in 1897. He used the mass spectrometer to uncover the first evidence for the existence of nonradioactive isotopes. His device for the determination of mass-to-charge ratios of ions was based on turn-of-the-century research on kanalstrahlen, the streams of positive ions formed from residual gases in cathode ray tubes, initially found emitted from channels cut in the cathode plate. Local magnetic and electrostatic fields deflected these positive rays depending on their mass, resulting in diverging traces on a photographic plate.

Thomson’s protégé, Francis Aston, designed a mass spectrometer in which ions were dispersed by mass and focused by velocity, improving resolution power by an order of magnitude over Thomson’s device. Other helpful innovations followed but the innovation of TOFMS as an analytical tool took several more decades. The concept was first presented at the 1946 APS April Meeting in Cambridge, Massachusetts, by William Stephens of the University of Pennsylvania.

The first TOF instruments were designed and constructed in the late 1940s, and the Bendix Corporation in Detroit, Michigan was the first to commercialize such devices. Two staff scientists — William Wiley and I.H. McLaren — are credited with devising a time-lag focusing scheme that improved mass resolution by simultaneously correcting for the initial spatial and kinetic energy distributions of the ions. The resolution was improved further by a 1974 invention by a Russian scientist, Boris Mamyrin, called the reflectron, which corrects for the effects of the kinetic energy distribution of the ions.

The quest for ever-greater resolution continues with two recently developed techniques: electrospray ionization (ESI) and matrix-assisted laser desorption/ionization (MALDI). In ESI, first conceived in the 1960s, highly charged droplets in an electric field are evaporated and the resulting ions are drawn into a mass spectroscopic inlet. MALDI, a form of laser desorption developed in 1985 by a team of German scientists, laser-desorbs sample molecules from a solid or liquid matrix containing a highly ultraviolet-absorbing substance.

These innovations have made TOFMS and other forms of lower-cost mass spectroscopy increasingly useful for sophisticated biomedical analysis, sufficiently democratizing the technology to make it available to hundreds of researchers who lack access to sophisticated magnetic sector machines. Current applications include the sequencing and analysis of peptides and proteins, DNA sequencing, and the analysis of intact viruses, among others, providing high sensitivity, specificity, and speed at a lower cost.

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Institute Participants Ponder Archimedes' Principle

These investigators are working with materials from an exemplary elementary science kit on buoyancy. The two at the right have just calibrated their spring scale and are weighing a large fishing bobber. The two at the bottom right are weighing a set of identically sized and shaped cylinders under water to determine the buoyant force.

All four were participants at the 2001 APS Lead-Scientist Institute, held in Washington, DC on January 6-10. This institute, the last in a series of seven funded by the Campaign for Physics, showed 46 scientists and educators from nine states how they can contribute to K-8 systemic science education reform.

After three days of talks and workshops, the participants observed science classes at an elementary and a middle school in nearby Montgomery County (MD) so they could see good science instruction in action. In addition, they toured the science materials center that replenishes the kits after each use in schools.

The APS expects that institute participants will work with teachers, administrators, and local officials and will recruit large numbers of scientists and engineers. The institute was conducted by Ted Schultz, a retired IBM physicist who is on the APS staff.

Photos by Edward Lee/APS

Top photo: Don Brown (left), Wallace Planetarium, Fitchburg, MA; and George Miller, Fitchburg State College.

Bottom photo: Carolanne Buguey (left), Webster Life Science Academy, Palo Alto, CA; and Bonnie Schindler, San Diego USD.

Memorial Talk To Honor Herman Feshbach

The upcoming APS April Meeting in Washington, DC, will feature a special memorial talk in honor of Herman Feshbach, a prominent nuclear physicist and former APS president (1980) who helped develop the theories underlying the behavior of the nuclei of atoms and later became active in the anti-nuclear movement. Feshbach died last December from congestive heart failure; he was 83.

The talk, "A Tribute to Herman Feshbach" will be delivered by J. Dirk Walecka, Governor's Distinguished CEBAF Professor of Physics at the College of William and Mary. It will be part of Session Q2, of the Division of Nuclear Physics, at 10:45am on Monday, April 30 in the Grand Ballroom South of the Renaissance Hotel.

A New York City native, Feshbach spent the majority of his professional career at the Massachusetts Institute of Technology, beginning as a graduate student in physics and eventually heading the physics department and serving as director of the Center for Theoretical Physics. He is best known for his description of the phenomenon now known as Feshbach resonance, in which two atoms adhere to form a temporary molecule when their kinetic energy is exactly equal to the energy required to bind them together. (Normally, when two atoms collide, they bounce off one another, akin to billiard balls.) He was awarded the National Medal of Science in 1986. In 1953 he co-authored (with Philip M. Morse) a two-volume textbook, *Methods of Theoretical Physics*, which served as the standard reference for physics graduate students for decades.

Reprinted from Shelter Island II

Discussing physics informally (left to right): R. Feynman, H. Feshbach, J. Schwinger at the Shelter Island Conference in 1947.

Feshbach's opposition to nuclear weapons dated back to the early 1950s, when he turned down an offer from Edward Teller to develop the hydrogen bomb, and in 1989 he was one of several scientists who signed a letter urging the US not to build new reactors for the production of weapons-grade uranium and plutonium. He was also a staunch supporter of human rights, co-founding the Union of Concerned Scientists and serving as its first chairman. In 1969 he participated in a "research stoppage" protesting military research at MIT, and later championed the cause of Soviet dissident physicist Andrei Sakharov.

AIP Report, *from page 1*

departments showed an increase in the percentage of hires who earned PhDs outside the US.

For 2001, the departments have an estimated 509 tenured and tenure-track faculty openings, not all of which will be filled. This is also a large increase from the previous survey, which showed 34% of departments recruiting for an estimated 373 tenured or tenure-track positions for 1999. And most of the 2001 recruitments (roughly three quarters) were for PhD granting physics departments. Physics departments also hired an additional estimated 329 faculty on a part-time or temporary full-time basis, for an estimated overall total of 658 new faculty, including tenure and tenure-track positions.

This increased demand for physics faculty is occurring at a time when the pool of potential faculty (among US PhD recipients) is decreasing. PhD production has been declining since 1994, dropping to 1262 for the class of 1999, according to AIP's most recent survey of enrollments and degrees. In addition, the number of incoming graduate students declined during the early 1990s and was still low in 1999, and thus the workforce survey report predicts that production will continue to be low, perhaps declining to around 1050 by 2003.

Czujko describes this trend as "disquieting," particularly when combined with the fact that the number of US citizens entering graduate school is in a free fall. "Over the last three years, the number of first-year students in graduate physics programs has stabilized, but this is due entirely to a continued increase among foreign students," he says. The number of US citizens entering graduate physics programs is the lowest in the 30 years that AIP has conducted such studies.

However, Czujko points out that the academic job market is influenced by many factors, all of which must be considered when predicting its future. "The pool of potential physics faculty is indeed getting smaller and it is tempting to compare the increasing number of openings to the decreasing number of new PhDs awarded each year," he says. "But such a comparison does not take into account the complexities of the academic job market for physicists. It is true that there are fewer applicants and more jobs than there have been in the last several years, and we do not foresee this situation changing for the next several years."

On the negative side, the report found that very few academically employed physicists are African-American or Hispanic, and two-thirds of African-American physics faculty work at historically black colleges and universities (HBCUs). Out of the 38 African-Americans who are on faculties at PhD-granting physics departments, fourteen belong to just two departments: Hampton University and Howard University.

Campinas Workshop Could Be the Start of a Series

The success of a recent summer workshop in Brazil, partly sponsored by APS and organized with the help of the APS Office of International Affairs, may augur well for a series of such workshops at appropriate locations throughout Latin America.

The meeting, held from February 11 to February 13, combined a workshop on the use of synchrotron radiation for research with a symposium on nanotechnologies. The site was the National Synchrotron Light Laboratory in Campinas, Brazil, and the Chair of the Organizing Committee was the founding director of this facility, Cylon Gonçalves da Silva.

The meeting was put together in eight months of concerted effort. "It was surprising to see how, on such short notice, we could get together a good number of scientists from several countries in Latin America", commented da Silva. "This shows such meetings are needed. The venue was well suited to showcase the determination of many countries in Latin America to support research and to provide high-quality scientific infrastructure."

Among the lecturers were ten from the United States, including Richard Pratt of the University of Pittsburgh. "The workshop in Campinas was very useful," he said, "for understanding what has been accomplished, and for becoming acquainted with the people there, others in Brazil, and more generally throughout the Americas."

This month, organizers of the meeting, together with representatives of the APS and of the US Liaison Committee to the International Union of Pure and Applied Physics, plan to get together to discuss future meetings in Latin America. "Many participants were extremely positive," said da Silva, "suggesting that the workshop should become part of a regular program of meetings on synchrotron radiation and nanotechnology in Latin America."

Pratt had a similar opinion, remarking that "the concentrated activity in a short time frame could provide a model for other such workshops in the future."

Courtesy of LNLS

Inter-American Workshop on the use of Synchrotron Radiation for Research and Symposium on Nanotechnologies hosted by Laboratório Nacional de Luz Síncrotron, Campinas-SP-Brazil, February 11-13, 2001.

LETTERS

Science Textbooks Riddled with Errors

Instead of debating philosophical subjects, such as "Religion and Science", I believe we should concentrate our minds and efforts on problems within our large realm of science teaching. A recent study of the science textbooks widely used in middle schools has shown them to be riddled with errors. The study is entitled, "Review of Middle School Physical Science Texts", and is authored by Dr. John L. Hubisz, visiting professor of physics at North Carolina State University. He is a coinvestigator in the 2½ year study, sponsored by a grant from the David and Lucile Packard Foundation.

The full report can be seen on the internet at: http://www.psrc-onhne.org. It is a devastating and disturbing account. While gross errors, such as showing the equator passing through the United States, leap out at the reader, they do not compare with the damage done by discouraging the young students. Experiments that can not possibly work, irrelevant photographs, diagrams and drawings that represent impossible situations, and patently false statements serve only to drive away potential science students. The damage is compounded by lack of response from the publishers, and the inability of the investigators to contact the real authors.

How can we claim respect and acceptance of science, when such pervasive and destructive teaching is allowed? This did not happen overnight – we have not paid attention to this growing problem in our children's schools. Where is the attention of the APS members and directors? We must attack this problem in our own back yard!

David A. Lupfer
Southern Pines, NC

Keyworth Promotes Reagan-Bush-Bush Agenda

I am writing in response to George Keyworth's Back Page article in the February *APS News* where he promotes the Reagan-Bush-Bush agenda of deploying the SDI system using high power lasers. He claims that only marginal attention has been paid to this technology over the past 20 years. However, the reality is that we have poured over 100 of billion dollars into the Star Wars program and have yet to produce a working system. We still cannot produce a laser or a rocket capable of destroying a missile or a surveillance system that can accurately identify one. In addition, it would be relatively easy to harden a missile against a laser attack: a highly reflective and conductive cladding should be sufficient.

Also (and I am not the first to state this), deployment of an anti-missile system would just induce other countries to build more missiles to overwhelm it. It is especially dangerous to build such a system (at a cost of over $100 billion) when it does not work.

Michael Bleiweiss
Methuen, Massachusetts

Physicists Obsess Over Small Part of Religion

Anantanarayanan Thyagaraja added Lysenkoism to the list of false belief systems that have inflicted suffering on millions. But I must dispute this claim. Lysenkoism by itself never did anything to anyone. Lysenkoism was a movement in biology that was supported by Stalin for political reasons. Lysenkoism was never at any time a driving force behind Communism. Quite the opposite.

It was the Soviet Communist Party that inflicted suffering on millions. They did it because the leadership thought cruelty and suffering were a valid means of building a society that replaced religious belief by scientific reasoning in the name of constructing and maintaining a scientifically engineered socialist economy.

But this suffering was not merely or simply imposed from the top down. It was a fully collective effort, inflicted by citizens upon other citizens. Family, friends and lovers were willing and eager to betray each other to the system. The deep reach and lengthy persistence of Stalinist suffering depended on the ability of one human to see another human suffering and then turn away without guilt or a sense of responsibility for the suffering.

As poet Anna Ahkmatova said about the year 1956 when the surviving prisoners of the Stalinist labor camps began to return home, "The half of Russia who went to the camps came home to face the half of Russia who sent them there." Physicists continually obsess over the small portion of religious thought and discourse that attempts to describe the external world. (Sometimes this reminds me of Napoleon obsessing over the parts of Europe that weren't ruled by France.)

But the majority of religious thought and discourse in the world does not concern the structure of spacetime or behavior of objects in the material world. The majority of religious thought in the world concerns the development of the individual's relationship with self and others. Some questions that religion asks and then tries in various ways to answer are: What should one human do upon seeing the suffering of another human? In what sense is the individual responsible for any part of the suffering of others? Who is guilty and who is innocent? And if there is guilt, what should the punishment be, and then what should happen after the punishment is delivered? And how can such suffering be alleviated? What actions and words and ideas have the power to bring solace to those who suffer?

Science, and especially physics, can never replace those thoughts or those conversations. The only responsibility felt by scientists is the responsibility to be correct about science. The scientific community spends a great deal of time arguing that this is where individual responsibility ends within the context of science.

The problem in the Soviet Union was that they did try to replace that thinking and conversing with what was at the time believed to be logical scientific reasoning. The tragic outcome of this endeavor should tell us something about where science belongs and where it should never try to go.

Patricia Schwarz
Pasadena, California

Letters Policy Now Online

APS News encourages our readers to submit letters to the editor. The best way to do this is to send them to letters@aps.org. Our policy on publishing letters can be found on the web at http://www.aps.org/apsnews/letters.html

zero gravity

A Fuga Really Big Numbers

By Alistair Cockburn

Every parent knows that kids like to hurl really big numbers at each other. It starts with the five- and eight-year-olds.

"My space commander rules the whole world!"

"Yeah, well my space commander rules the whole star and all the planets."

"Yeah, well my commander rules two stars."

"Mine rules ten stars."

Now is the big moment for the five-year-old. Five-year-olds have to learn to count to 100 in kindergarten, so One Hundred is a really big number. It is so big and frightening to five-year-olds that they never name 101. Always 100.

"My space commander rules 100 stars!"

At this point the five-year-old will lose, because the eight-year-old can say, "Well mine rules 1,000 stars, so there." And the five-year-old can't say anything.

But the ten-year-old can, and jumps in with, "But my commander rules a million stars."

And now the five-year-old is back in the game. "Well my space commander rules a million million million million million million..." and keeps going until the other two walk away or mom or dad show up and say, "Quiet down in here and just play."

What kids need are some really big numbers. A jillion is good for a while, but it is not a real number, it's a fake. Quintillion is great if you can say it.

My kids were seriously impressed with googol, and even more impressed that it was named by a ten-year-old in search of a really big number. I can almost hear the conversation at the dinner table. The ten-year-old has recently learned about powers of ten:

"Dad, what's 10 to 5th power?"

"Ten thousand."

"Dad, what's 10 to the 10th power?"

"Ten billion." [Silence for a bit.]

"Dad, what's 10 to the 100th power?"

"It doesn't have a name." [Silence again.]

"I want to call it 'googol'."

"OK, that's fine."

"Dad, what's 10 to the googol?"

"Well, googol didn't have a name until a few seconds ago, so 10 to the googol doesn't have a name."

Power surges through the ten-year-old at the thought of having found a specific, real number that is so big it doesn't even have a name. The two decided on the name "googolplex," and they made the names public and popular. So that now, in our household, the conversation between the three kids runs on its course:

"Well, my space commander rules a googol stars!"

"Well, mine rules a googolplex stars!"

And they are stuck again. What we need are names for some seriously, really big numbers, bigger even than googolplex.

Let's first get straight that googolplex is a really big number. Googol is 10 to the 100th power, which is 10,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000. Googolplex isn't just that number but has that many zeros in it. It simply has no other nameable name.

But it's no good having a top number. Kids need numbers beyond numbers, ways to name number larger than whatever numbers the other kids name. And they have to be actual numbers, not phonies like "jillion," or vague not-quite-numbers like "infinity." Part of the game is to keep using up more number names.

I have been obliged to find ways to make numbers grow faster and faster. My by-now six-year-old, Kieran, caught the other two off guard one day: "Mine rules gargoogolplex stars. Gargoogolplex is googolplex googolplexes." I liked the cleverness of Kieran's "gar-" prefix. It implies that there are as many of the number as the number itself. For example, "gar-four" is four fours. "Gar-million" is a million millions. And "gar-googolplex" is a googolplex googolplexes.

However, kids in junior high get around to noticing that four fours is really just four squared (4 x 4 = 4^2), and a million millions is a million squared (1,000,000 x 1,000,000 = $(1,000,000)^2$). Much more interesting would be to get $1,000,000^{1,000,000}$, which doesn't have a name, as far as I know. But then, some of us have lived long enough to see what's coming. We won't just need a name for $1,000,000^{1,000,000}$, but a name for: N^N, any number to the power of itself. Let's call it fz-whatever. Fz-four is 4^4, and fz-million is the $1,000,000^{1,000,000}$ we were looking for. We can already see where this is going. Fzgoogolplex is going to outdo gargoogolplex in just a moment, because gargoogolplex is only $googolplex^2$, and fzgoogolplex is $googolplex^{googolplex}$, and nobody is going to top that.

Not so. We made our own new math function, Fuga, to take us one step further in this game. We noticed that fzgoogolplex only has googolplex raised to the googolplex once. What about the ultimate five-year-old's answer? "Googolplex raised to the googolplex raised to the googolplex raised to the... (until the voice wears out)."

We came up with fuga (pronounced 'few-ga'). Fuga is a mixture of the musical word "fugue," and Kieran's "gar-" prefix. Fuga-number means "that number raised to that number that number of times." Fuga-2 is (2^2). Fuga-3 is $((3^3)^3)$. Very soon, here, this is going to get hard to write. So we will leave fuga-4 and fuga-100 as exercises for the reader. Now we can name Fuga-gar-googolplex! (We could say fuga-googolplex, but why bother when we know that Kieran is just going to say Fuga-gar-googolplex right afterwards?)

There we have it. A number so big that it boggles the ears just in the speaking. Gar-googolplex raised to the gar-googolplex a gar-googolplex times! Bigger than the number of all the atoms in the universe! [By a lot! Ed.]

PHYSICS AND TECHNOLOGY FOREFRONTS

Frozen Light: the Tip of the Iceberg

By Marlan O. Scully and George R. Welch

Recent experiments have slowed light, stored light, and even demonstrated the possibility of bringing light to a complete halt and reversing its direction. These experiments now pave the way for a wide-ranging set of applications including new measurement tools in the near term to quantum optical data storage and processing in the more distant future.

In 1967, Hahn and his coworkers used self-induced transparency to reduce the group velocity of light to around c/100. This was startlingly low at the time, but like all records it was quickly surpassed. Today, using electromagnetically induced transparency (EIT) and capitalizing on the ultra-dispersive nature of EIT, it stands near one meter per second.

Last year, a theoretical analysis by Lukin, Yelin, and Fleishhauer, followed by beautiful experiments on the storage of light in atomic vapor, showed that quantum information associated with a light field can be stored for long times and retrieved on demand. Furthermore, within the past year calculations have shown that light can actually be "frozen" or stopped by making use of the Doppler broadening associated with a hot gas.

Group Velocity and Frozen Light

There are several kinds of velocities associated with optical phenomenon in dispersive media. The phase velocity, v, is the speed at which the nodes of the electromagnetic carrier wave moves. This is defined as $v = c/n$ where n is the index of refraction. But the group velocity, which is the velocity v_g of the peak of the electromagnetic envelope or wave packet, is more important for the present purposes. This is usually given by $v_g = c/n_g$ where n_g is the group index, and $n_g = 1 + \omega\partial n/\partial\omega$ where ω is the frequency of the light. By making the group index large, on the order of 10^6 or 10^7 as in recent experiments, it is possible to slow the velocity of light to a few tens of meters per second.

But there is more to the story. When the index of refraction n depends on the wave-vector k, such as when atoms are moving in a Doppler broadened medium, the correct expression for the group velocity is $v_g = (c - \omega\partial n/\partial k)/n_g$. The second term in the numerator is potentially very large, and in this way it is possible to use the thermal motion of the atoms to stop or "freeze" the light.

Stored Light

The plot thickens when one realizes that the ultra-large nonlinearity associated with slow light plays an important role even for very weak light pulses. Harris and Hau showed that nonlinear optical effects are important even at the single photon level. In fact, Lukin, Yelin, and Fleishhauer and Lukin and Imamoğlu showed theoretically that one can control and manipulate the quantum state of pulse with another pulse of light as weak as a single photon. They also showed that it should be possible to store the quantum states of single photon fields in the atomic medium and to read the stored quantum information with nearly 100% efficiency via a pulse applied later in time. Recently Philips and colleagues at the Harvard Smithsonian and Liu and colleagues at the Rowland Institute carried out the first proof-of-principle experiments. Using polaritons, the strong coupling of light and matter in ultra-dispersive media, they demonstrated that quantum memory could be efficiently recorded and read out.

Quantum information theory, quantum computing, quantum dense coding and the like are all potentially exciting applications of these new phenomena. But the time scale for their use is still anybody's guess!

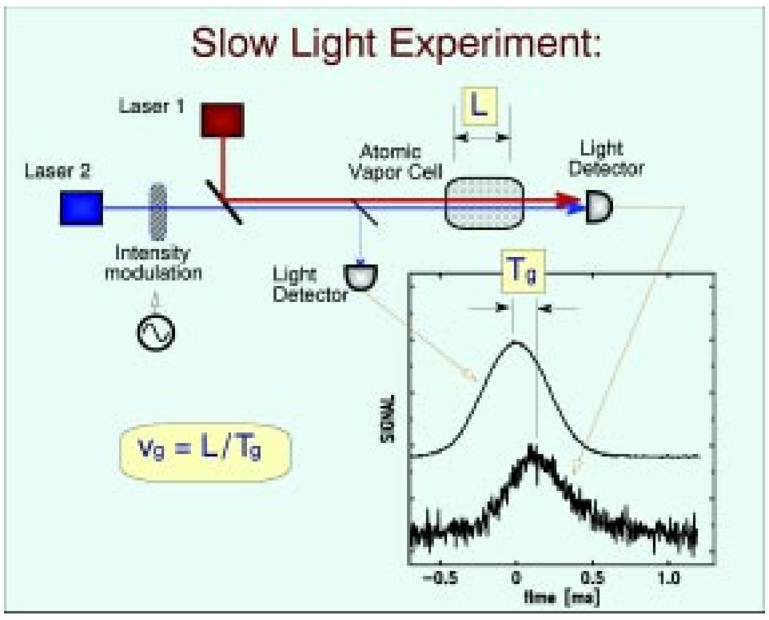
Recent Experiments

The sense in which light can be said to be "stored" in recent experiments is similar to the spirit of teleporting an atom by transmitting the quantum information necessary to reproduce the original atomic state. The idea of teleportation is that the quantum state of an atom can be imprinted on an electromagnetic field, this field can then be transmitted to another point in space and time, and then the information contained in the light beam can be used to prepare an atom in the original state. All atoms are identical, so we can say that we have teleported the atom from one point to another.

Philips and Liu turned things around in their experiments on atomic coherence. They focused on the fact that it is possible to store the quantum state of a light beam in an atomic medium and then allow the atoms to evolve such that the same light beam can be reconstructed later in time. In this sense the atoms are used to store the state of light.

At Texas A&M University we have demonstrated new results on light transportation (transport of the state of light between different spatial and temporal points via atomic coherence), multiplexing (transfer of a state of light with one frequency and wave vector to another frequency and wave vector), and time reversal (phase conjugation). We use the fact that the atomic center of mass motion allows us to transport the stored information from one point in space to another. Thus, we provide proof-of-principle demonstrations of the tools to teleport light via atomic motion, i.e., the moving atoms carry the information about the light between two spatially separated points.

This technique also enables us to time reverse the incident pulse by extracting its time reversed phase conjugate partner from the stored information. In this sense, our experiments may be viewed as an extension of stimulated photon echo experiments, as originally carried out in two level systems, and more recently generalized to multilevel media and to resonant four-wave mixing experiments in coherent atomic systems. However, the usual photon echo experiments do not involve "photons", i.e., they involve only intense *classical* fields rather than single photon *quantum* fields.



Due to the giant non-linear optical coefficients associated with EIT, our experiments are capable of demonstrating nonlinear optical effects at the few-photon level. Furthermore, unlike photon echoes, there is no time delay between the reading and restored pulses associated with the spin restoration in an inhomogeneously broadened medium. The Doppler-free configuration of the fields allows us to reproduce the signal pulse at any moment of time, provided that the spin-coherence survives. Finally, unlike other resonant four-wave mixing experiments, we can spatially and temporally separate the writing fields (which store the information in the atomic medium) from the reading field. Therefore our experiments demonstrate a new facet of quantum coherence.

Applications of Slow, Stored, and Frozen Light

New Acousto-Optics

The world of acousto-optics has always been dominated by the fact that light moves much faster in a medium than sound. But now, ultra-slow light can give us a new lease on life, acousto-optically speaking. For example, stimulated Brillouin scattering in ordinary experiments is only observed in the backward direction because of the need to phase-match the sound and light fields. When ultra-slow light interacts with sound waves and the light velocity equals the velocity of sound in the medium, an anomalous stimulated Brillouin scattering occurs such that the generated sound is strongest in the forward direction and vanishes in the backward direction! Furthermore, using the extreme phase matching made possible by ultra-slow light in a fiber, we can achieve enhanced squeezing via guided acoustic wave Brillouin scattering.

As a second example, it is possible to dramatically increase the efficiency of the ponderomotive nonlinearity driving the atomic media by appropriately detuning the light fields from atomic resonance. Harris has shown that the longitudinal gradient force acting on a two-level atom can be enhanced very substantially via the spatial compression associated with ultra-slow pulse propagation. This enhanced force provides a kind of atom "surfing" and a new kind of local ponderomotive light scattering.

See FOREFRONT *on page 7*

50 Years on Long Island

APS Editor-in-Chief Marty Blume accepts "50 Years of Physical Review on Long Island" proclamation from Suffolk County Legislator Ginny Fields at APS Editorial Offices.

Bob Kelly/APS

A "50 Years on Long Island" celebration bagel breakfast for staff and guests was held at the APS Editorial Office in Ridge, NY on 15 February, to coincide with the first issue produced on Long Island 50 years ago. Peter Bond, former Interim Director of Brookhaven National Laboratory, was in attendance as was Suffolk County Legislator Ginny Fields. Fields addressed the staff and presented a congratulatory proclamation from the County Legislature.

Founded at Cornell University in 1893, the *Physical Review* remained based at or near that institution until 1926, when it relocated to the University of Minnesota and John Tate became Editor. At his death, an interim Editor took over for a year until the operation moved to Long Island and Sam Goudsmit of Brookhaven National Laboratory became Editor.

From its beginning until 1951, the *Physical Review* operation was nimble and compact enough to be relocated when the Editor changed. But well before the end of Goudsmit's term in 1975 it was clear that henceforth the Editor-in-Chief would need to come to the journals, rather than vice versa. So it happens that the best physics journals in the world, by almost any measure, are put together in the peaceful and beautiful environs of eastern Long Island's Suffolk County.

VIEWPOINT…

Science and Surpluses *By D. Allan Bromley*

When President Bush spoke to Congress and the nation on Feb. 27, he outlined three cardinal goals: a $1.6 trillion tax cut, a first-class education for every child and a restructured military that confronts emerging post-cold-war threats. The next day, he announced a budget that jeopardizes the nation's ability to achieve any of these truly laudable goals.

Both the tax cut and the spending that would support educational and military buildups depend upon an estimated $5.6 trillion surplus over the next 10 years. Where is all that money coming from? There are several sources, but the major driver of our nation's economic success is scientific innovation. And the Bush budget includes cuts, after accounting for inflation, to the three primary sources of ideas and personnel in the high-tech economy: the National Science Foundation is cut by 2.6 percent, NASA by 3.6 percent and the Department of Energy by an alarming 7.1 percent.

Economists, including Alan Greenspan, attribute much of America's 1990s boom to increased productivity stemming, in large part, from scientific research. Two simple discoveries * the transistor and the fiber optic cable * are at the root of it. Anyone skeptical of this should turn off the computer for a day and see how much work gets done.

The 21st century economy will continue to depend on scientific innovation. Economists estimate that innovation and the application of new technology have generated at least half of the phenomenal growth in America's gross domestic product since World War II. Keeping that economic source productive is critical to both national prosperity and federal revenues. (And where defense is concerned, basic scientific discovery also has a more direct role: it leads to the applied science that eventually provides advances in defense hardware.)

Technological innovation depends upon the steady flow of discoveries and trained workers generated by federal science investments in universities and national laboratories. These discoveries feed directly into the industries that drive the economy. It's a straightforward relationship: industry is attentive to immediate market pressures, and the federal government makes the investments that ensure long-term competitiveness.

The proposed cuts to scientific research are a self-defeating policy. Congress must increase the federal investment in science. No science, no surplus. It's that simple.

Ed. Note: D. Allan Bromley, Sterling Professor of the Sciences at Yale, served as Science Advisor to President Bush the elder, 1989-93, and was APS President in 1997. This article appeared in the New York Times on March 9.

Master's Program Enhances Relevance of Physics to Zimbabwe

Xavier Carelse speaking in College Park and (inset) working with students in Zimbabwe.

Ed. Note: This story was written for APS News by Jordan Raddick.

"We are progressively making physics irrelevant by focusing on what physics is and what it isn't," claimed Xavier Carelse, professor of physics at the University of Zimbabwe, in a talk given at APS headquarters in February.

Carelse contrasted this general situation with the Master's of Applied Physics program that he founded at the university in 1994. His students work with industry to learn new machines and techniques, and most graduates go on to jobs with industries in Zimbabwe. "What we're trying to do is to make physics relevant to our country," Carelse said.

Carelse grew up in South Africa. He has worked in eight different countries, and has been at the University of Zimbabwe in Harare for twenty years. Last September, Carelse gave a presentation at an international conference on physics and economic development in Durban, South Africa. There, he met Roman Czujko, Director of the Statistical Research Center of the American Institute of Physics (AIP). When Czujko heard that Carelse was coming to Washington, he invited him speak at the American Center for Physics, the common home of APS and AIP, in College Park, MD. "His talk and the slides that he used put a face on physics in Zimbabwe," Czujko said.

In his talk, Carelse explained that his university is currently experiencing the same decline in physics enrollment that many western universities have experienced. He attributes the decline to an excessive focus by professors on defining 'pure' physics and steering students away from jobs in government or industry.

To solve this problem, Carelse founded his two-year master's of applied physics program. In the first year, students take classes and pick one of four areas of concentration. One course involves practice in a workshop that Carelse built for the students. Students make devices in the workshop; by the end of the course, all must be able to design and build a circuit. One student built a solar cooker – he now uses it to cook all his food, and he sells it in the countryside. "You can't train physicists to be useful in industry unless you train them to use their hands," Carelse said. One of his PhD students turned a broken electron microscope into a plasma focus machine, and he now uses it to conduct fusion experiments. Carlese said he knows when the machine is running because it makes a loud bang that can be heard throughout the building.

In the second year of the master's program, students are matched up with local companies for an internship, where they work as full-time industrial physicists. Since 1993, 30 students have graduated from the master's program. Many have gone on to other industrial jobs, both in Zimbabwe and abroad. Half of the graduates have taken teaching jobs. "To me, that is gratifying," Carelse said. "They will produce the next generation of physicists who are relevant to Zimbabwe." One recent graduate has gone to the nearby country of Malawi, where he is setting up a similar university master's program.

April Meeting, *from page 1*

level of 2.6 standard deviations from the predicition of the Standard Model.

Session H7, sponsored by the Division of Nuclear Physics, will be a Mini-Symposium on Early Results from RHIC, and will feature talks by representatives of all four major experiments at the Relativistic Heavy-Ion Collider: J. J. Gaardhoje of the Niels Bohr Institute (BRAHMS); Marzia Rosati of Iowa State (PHENIX); Steven Manly of the University of Rochester (Phobos); and Peter Jacobs of Berkeley (STAR).

Renaissance Congressional A, Sunday morning at 10:45

Session J2 on Progress in Neutrino Physics is jointly sponsored by DPF and DNP and among its highlights will be a talk on results from the Sudbury Neutrino Observatory (SNO) by Kevin T. Lesko of Berkeley and the Maria Goeppert-Mayer Award talk by Janet Conrad of Columbia University.

Renaissance Grand Ballroom South, Sunday afternoon at 2:30

Going Ballistic on Missile Defense

One of the key technical questions in the ongoing debate about the feasibility of national missile defense systems (NMDs) is whether they can be expected to work under real-world conditions if the attacker has taken steps to defeat the defense. In fact, the APS Council has approved a new APS study to analyze a possible boost-phase intercept system (see *APS News*, January 2001). This issue will be addressed by several speakers, among them Richard Garwin, a senior fellow for science and technology for the Council on Foreign Relations, who will discuss a proposal to conduct boost-phase intercepts, along with other simple possible countermeasures and the US's possible response to them. "The NMD organization has not seriously considered countermeasures, which I believe are much easier to build than the ICBMs themselves," he says. "Only now is NMD beginning to structure a program to evaluate and determine the response to such countermeasures."

Lisbeth Gronlund of MIT's Security Studies Program, also a member of the Union of Concerned Scientists, will follow Garwin's lead in considering three primary potential countermeasures an emerging missile state could employ to overcome an NMD defense system. She is also a speaker at a Sunday morning session featuring this year's recipients of prizes sponsored by the APS Forum on Physics and Society; Gronlund will discuss the role of testing in the development of a weapons system and make recommendations as to what an adequate NMD test program might look like. Her MIT compatriots, George Lewis and David Wright, will review the use of the Patriot air defense system in the 1991 Gulf War, and the impact of the development of ballistic missiles by North Korea, respectively.

Session S1, Grand Ballroom North/Central; Session H2, Grand Ballroom South

Securing Scientific Freedom

Continuing controversy over security lapses at the national laboratories and routine polygraph testing of defense employees has prompted the organization of a special panel discussion on Saturday afternoon on balancing the need for scientific freedom with national security interests. Scheduled panelists are Ernest Moniz, former Undersecretary of the Department of Energy (DOE), John Browne of Los Alamos National Laboratory, Charles Shank of Lawrence Berkeley Laboratory, and John Hamre of the Center for Strategic and International Studies, the chair of a new commission to study security issues at the national laboratories of DOE (see *APS News*, February 2001). And on Monday evening, the Forum on Physics and Society is sponsoring a special session on polygraph testing, one of the key issues under debate in the recent Los Alamos controversies.

Session T1, Room 3

The Search for Signs of Eternal Life in an Eternally Expanding Universe

Tackling the ambiguous complexity of "life, the universe, and nothing," bestselling science author Lawrence Krauss (*The Physics of Star Trek*), a professor of physics at Case Western Reserve University, will give this year's Lilienfeld Prize lecture on Saturday afternoon. His theme is life and death in an ever-expanding universe, starting with recent observations in cosmology "that have changed the way we think about the universe on large scales," extending the discussion to the implications for life, and closing with the question of whether life can be eternal in an eternally expanding universe. "Surprisingly, the answer to this question appears to hinge on questions of basic physics, in particular issues of quantum mechanics and computation, which may determine whether life is ultimately analog or digital," he says. The session will also feature the annual retiring presidential address, delivered this year by APS Past President James Langer.

Session E1, Grand Ballroom North/Central

Celebrating A Constant Centenary

The National Bureau of Standards' National Institute of Standards and Technology (NIST) celebrates 100 years of its congressionally mandated mission to improve scientific knowledge of the values of the fundamental physical constants, as part of its responsibility for stewardship of the national standards of measurement. The APS is marking the occasion with a special session devoted to NIST and the NBS, featuring a lecture by Harvard University's Lewis Branscomb, who joined the scientific staff of the NBS in 1951 and headed agency from 1969 to 1972. Branscomb will emphasize the importance of the agency's reputation for scientific integrity, illustrated with various case studies. The session also includes talks on other highlights in the agency's long history, as well as H. N. Russell's spectroscopic work in the analysis of complex spectra, the story of Bose-Einstein condensation, and an overview of the scientific legacy of Ugo Fano, who joined the NBS staff in 1946.

Session H6, Auditorium

Warming Up to Climate Change

The task of adapting and coping with climate change is made more daunting "because climate and weather impact society largely through extremes," according to Hugh Pitcher of Pacific Northwest National Laboratory, one of the featured speakers at a Monday morning session on climate change. In order to forecast societal impact, he believes we need a predictive understanding of how projected climate change will reflect or impact extreme events — a capability that does not yet exist. However, "By studying how societies worldwide build resilience to today's weather extremes, and by adopting best practices locally, we can go a long way toward building global resilience with respect to future climate change," he says.

Agent-based computer modeling is now being used to grow artificial societies and model the socio-economic systems of the past, according to George Gumerman, director of Arizona State Museum and a professor at the University of Arizona, who will speak at the same session. He will describe how he used a computer program to model and systemically alter prehistoric economic and settlement behavior of the Anasazi in northeastern Arizona. Other speakers will focus on the economics of future energy sources, and the role of scientists in setting climate change policy.

Session Q1, Grand Ballroom North/Central

APRIL MEETING SPECIAL EVENTS

Saturday, April 28

5:00 PM - 7:00 PM

Awards Session

Presentation of the 2001 APS prizes and awards bestowed on individuals for outstanding contributions to physics. This session will also feature the Lilienfeld Prize Lecture and the retiring Presidential Address. See the Special Honors Insert, March 2001 *APS News*, for complete list of recipients and citations.

7:00 PM -

Welcome Reception

APS President George Trilling will help kick off the 2001 Meeting with a special welcoming reception, open to all attendees.

Monday, April 30

1:00 PM - 2:30 PM

Students Lunch with the Experts

Following its success at the last two APS March Meetings, the students' lunch with the experts makes its debut at the April Meeting. Each expert will host an informal discussion over a complimentary box lunch with students interested in his or her topic.

Tuesday, May 1

7:30 AM - 9:30 AM

CSWP Networking Breakfast

The APS Committee on the Status of Women in Physics is sponsoring a special networking breakfast, open to all with an interest in issues pertaining to women in physics, featuring a short talk followed by discussion and networking.

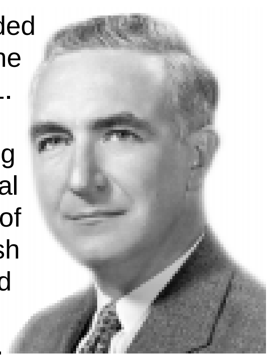
REMINDER

The 2001 APS Congressional Visits Days will be held during the April Meeting, May 1-2. Conference attendees are encouraged to stay an extra day in Washington, DC to participate in the event, which brings scientists, engineers, researchers, educators, and technology executives to Washington to raise visibility and support for science, engineering and technology. For more information and to sign up, contact Christina Hood at the APS Washington Office, 202-662-8700, hood@aps.org.

ANNOUNCEMENTS

CALL FOR NOMINATIONS

THE GEORGE E. VALLEY JR. PRIZE OF THE APS



The George E. Valley Jr. Prize will be awarded for the first time in 2002. Nominations for the 2002 prize must be received by July 2, 2001.

The prize will be awarded for outstanding research in any field of physics to an individual who is under the age of 30 at the time of nomination. The prize carries with it a cash award of $20,000. More details can be found on the APS web site at http://www.aps.org/praw/valley/descrip.html.

Five (5) copies of nominations and supporting documentation should be sent to:

Laleña Lancaster
Attn: George E. Valley Prize
American Physical Society
One Physics Ellipse
College Park, MD 20740-3844
lancaste@aps.org

Call for Nominations for 2002 APS Prizes and Awards

Members are invited to nominate candidates to the respective committees charged with recommending the recipients. A brief description of each prize and award is given in the March 2001 *APS News Prizes and Awards* insert, along with the addresses of the selection committee chairs to whom nominations should be sent. Please visit the Prize and Awards page on the APS web site at http://www.aps.org under the Prize and Awards button for complete information regarding rules and eligibility requirements for individual prizes and awards.

PRIZES

WILL ALLIS PRIZE FOR THE STUDY OF IONIZED GASES
HANS A. BETHE PRIZE
BIOLOGICAL PHYSICS PRIZE
TOM W. BONNER PRIZE IN NUCLEAR PHYSICS
OLIVER E. BUCKLEY CONDENSED MATTER PHYSICS PRIZE
DAVISSON-GERMER PRIZE IN ATOMIC OR SURFACE PHYSICS
DANNIE HEINEMAN PRIZE FOR MATHEMATICAL PHYSICS
POLYMER PHYSICS PRIZE
FRANK ISAKSON PRIZE FOR OPTICAL EFFECTS IN SOLIDS
JAMES C. MCGRODDY PRIZE FOR NEW MATERIALS
LARS ONSAGER PRIZE
GEORGE E. PAKE PRIZE ***(April 2, 2001 Deadline)***
W.K.H. PANOFSKY PRIZE IN EXPERIMENTAL PARTICLE PHYSICS
EARLE K. PLYLER PRIZE FOR MOLECULAR SPECTROSCOPY
ANEESUR RAHMAN PRIZE FOR COMPUTATIONAL PHYSICS
J. J. SAKURAI PRIZE FOR THEORETICAL PARTICLE PHYSICS
ARTHUR L. SCHAWLOW PRIZE IN LASER SCIENCE
PRIZE TO A FACULTY MEMBER FOR RESEARCH IN AN UNDERGRADUATE INSTITUTION
GEORGE E. VALLEY JR. PRIZE
ROBERT R. WILSON PRIZE

AWARDS

LEROY APKER AWARD ***(June 15, 2001 Deadline)***
JOSEPH A. BURTON FORUM AWARD
MARIA GOEPPERT-MAYER AWARD
JOSEPH F. KEITHLEY AWARD FOR ADVANCES IN MEASUREMENT SCIENCE
LEO SZILARD LECTURESHIP AWARD

MEDALS AND LECTURESHIPS

DAVID ADLER LECTURESHIP AWARD
EDWARD A. BOUCHET AWARD
JOHN H. DILLON MEDAL

DISSERTATION AWARDS

OUTSTANDING DOCTORAL THESIS RESEARCH IN BEAM PHYSICS AWARD
NICHOLAS METROPOLIS AWARD FOR OUTSTANDING DOCTORAL THESIS WORK IN COMPUTATIONAL PHYSICS
DISSERTATION AWARD IN NUCLEAR PHYSICS

NOMINATION DEADLINE IS JULY 2, 2001, UNLESS OTHERWISE INDICATED.

CORRECTION

In the "Physics News in 2000" insert in the February *APS News*, the item on Multiple-Ionization Mechanisms contained an error. The text incorrectly referred to lithium atoms, and should have read "...the helium collaboration performed subsequent electron-electron correlation measurements on ionized argon atoms;...". *APS News* regrets the error, and thanks Dr. Harald Giessen for pointing it out.

APS UNDERGRADUATE PHYSICS STUDENT COMPETITION

2001 APKER AWARDS

For Outstanding Undergraduate Student Research in Physics

Endowed by Jean Dickey Apker, in memory of LeRoy Apker

DESCRIPTION

Two awards are normally made each year: One to a student attending an institution offering a Physics PhD and one to a student attending an institution not offering a Physics PhD

- Recipients receive a $5,000 award; finalists $2,000. They also receive an allowance for travel to the Award presentation.
- Recipients' and finalists' home institutions receive $5,000 and $1,000, respectively, to support undergraduate research.
- Recipients, finalists and their home physics departments will be presented with plaques or certificates of achievement. The student's home institution is prominently featured on all awards and news stories of the competition.
- Each nominee will be granted a free APS Student Membership for one year upon receipt of their completed application.

QUALIFICATIONS

- Students who have been enrolled as undergraduates at colleges and universities in the United States at least one quarter/semester during the year preceding the **JUNE 15, 2001** deadline.
- Students who have an excellent academic record and have demonstrated exceptional potential for scientific research through an original contribution to physics.
- Only one candidate may be nominated per department.

APPLICATION PROCEDURE

The complete nomination package is due on or before **JUNE 15, 2001** and should include:

1. A letter of nomination from the head of the student's academic department
2. An official copy of the student's academic transcript
3. A description of the original contribution, written by the student such as a manuscript or reprint of a research publication or senior thesis (unbound)
4. A 1000-word summary, written by the student, describing his or her research
5. Two letters of recommendation from physicists who know the candidate's individual contribution to the work submitted
6. The nominee's address and telephone number during the summer.

FURTHER INFORMATION

See **http://www.aps.org/praw/apker/descrip.html**

DEADLINE

Send name of proposed candidate and supporting information by **JUNE 15, 2001** to: Dr. Alan Chodos, Administrator, Apker Award Selection Committee; The American Physical Society; One Physics Ellipse, College Park, MD 20740-3844; Telephone: (301) 209-3268, Fax: (301) 209-3652, email: chodos@aps.org.

Now Appearing in RMP...

The articles in the April 2001 issue of *Reviews of Modern Physics* are listed below. For brief **descriptions** of each article, consult the RMP website at http://www.phys.washington.edu/~rmp/current.html. *George Bertsch, Editor.*

Phonons and related crystal properties from density-functional perturbation theory — *Stefano Baroni, Stefano de Gironcoli, Andrea Dal Corso, and Paolo Giannozzi*
Spontaneous symmetry breaking in rotating nuclei — *Stefan Frauendorf*
Bose-Einstein condensation in the alkali gases: some fundamental concepts — *Anthony J. Leggett*
Quantum state engineering with Josephson-junction devices — *Yuriy Makhlin, Gerd Schön, and Alexander Shnirman*
M(atrix) theory: matrix quantum mechanics as a fundamental theory — *Washington Taylor*
W boson physics at hadron colliders — *Randy M. Thurman-Keup, Ashutosh V. Kotwal, Monica Tecchio, and Aesook Byon-Wagner*
Metallic behavior and related phenomena in two dimensions (colloquium) — *Elihu Abrahams, Sergey Kravchenko, and Myriam P. Sarachik*
Acoustical analogs of condensed-matter problems (colloquium) — *Julian D. Maynard*

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Forefront, *from page 5*

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New Nonlinear Optics

Ultra-slow light is being used in non-linear optical processes. There are many schemes for taking advantage of the enhanced nonlinearities, but in particular we focus on a four-wave mixing double-Λ scheme in which the ground state coherence is produced by one set of laser fields and a weak signal scatters off this grating, resulting in parametric amplification of the remaining fourth field. Sokolov in Harris' group at Stanford and Hakuta and coworkers in Japan have polished this technique to a fine art. They produce a comb of Raman signals with frequencies extending from infrared well into the deep ultraviolet. In the foreseeable future we expect these techniques to generate Fourier-transform-limited ultra-short pulses.

Recently Hemmer pioneered phase-conjugate nonlinear optics that Zibrov and coworkers have extended to the production of non-degenerate parametric self-oscillation. In this latter context, Harris many years ago suggested the possibility of mirror-less oscillation building up from a vacuum with counter-propagating fields. Recent experiments have demonstrated that the effective phase-conjugation is generated spontaneously by the large nonlinear gain and intrinsic feedback associated with the coherent grating. This type of oscillator has an extremely narrow Schawlow-Townes type line width governed by the group delay of ultra-slow light in the medium rather than the storage time of light in a laser. The group delay is on the order of milliseconds or even seconds, whereas the typical laser light storage time is on the order of microseconds. Thus, the quantum line width of mirror-less parametric oscillators based on coherent grating slow light propagation is already a subject of considerable interest to technologists.

Finally Tombesi et al. have presented a scheme for the complete quantum teleportation of a photon polarization state, made possible by using the ultra-large Kerr non-linearity. With ultra-slow light, their idea can be realized with presently available technology.

Conclusion

Ultraslow light and atomic coherence have already found many new applications in metrology, nonlinear optics at very low intensity, and in the interaction between light and *moving* atoms. Moreover, the coherence increases the coupling between light fields such that it becomes possible to study the interaction between single photons. It is already possible to store information about light and transport it in space and time, change its frequency, and time-reverse the light's propagation. The time when novel applications in quantum nonlinear optics and quantum information processing through the use of frozen light will fast be upon us.

Marlan O. Scully is Distinguished Professor of Physics, and director of the Center of Theoretical Physics. George R. Welch is an Associate Professor of Physics. Both are at Texas A&M University.

THE BACK PAGE

The Mathematics of One Person, One Vote

By H. Peyton Young

Article I of the US Constitution states that "representatives and direct taxes shall be apportioned among the several states . . . according to their respective numbers" but offers no specific rule for achieving this goal. The Constitution also requires a census every ten years to ensure that representation stays in line with changing populations. As expected, the 2000 Census numbers show a dramatic shift in population from the urban Northeast to the South and Southwest, and there will be a corresponding shift of twelve seats in the House of Representatives. But what method is actually used to determine this result? The answer forms a fascinating tale that spans two centuries and involves some of the country's greatest statesmen and mathematicians—with the most telling mathematical insights generally supplied by the former rather than the latter.[1]

Before launching into this story, however, the skeptical reader may be wondering what all the fuss is about. Why not simply compute the exact share of seats for each state (the *quotas)* and round them to the nearest integers? The difficulty is best illustrated by an example. Consider a federation of three states with a "house" of 21 representatives (see below).

Three State Federation with a "House" of 21 Representatives

State	Population	Quota	Hamilton	Quotient(480,000)	Jefferson
A	7,270,000	14.24	14	15.15	15
B	1,230,000	2.41	3	2.56	2
C	2,220,000	4.35	4	4.63	4

Here ordinary rounding does not work because all three states get rounded down, and thus only 20 seats are apportioned. The earliest proposed solution to this difficulty is due to Alexander Hamilton (1792): round the quotas in the usual way, and if any seats are left over, give them to the states with largest remainders. In the present example, state B, with remainder .41, would get rounded up to 3 seats under Hamilton's method.

Straightforward as this approach may seem, it is fraught with difficulties, as future experience would show. In the meantime, however, Thomas Jefferson (Hamilton's nemesis) argued that the method was fundamentally wrong-headed. The correct approach, said Jefferson, is to choose a common divisor, d, divide it into each state's population, and drop the fractional part of the resulting quotient. The "trick" is to adjust d so that the required number of seats is apportioned. This approach apportions each house size in an essentially unique way, because as the divisor is adjusted downwards (or upwards), exactly one state at a time gains (or loses) a seat, barring improbable ties. Jefferson's solution is shown above with a divisor of 480,000, but any divisor between 484,666 and 454,376 yields the same answer.

Jefferson prevailed over Hamilton in the 1790s debate—not because Congress recognized its mathematical subtlety, but largely because it gave one more seat to Virginia, which at that time was by far the most populous and most important state. Jefferson's method continued in use through the 1830s, even as it came under increasingly bitter attack in Congress because of its blatant favoritism toward large states. (If Jefferson's method were in use today it would give California 55 seats, even though California's quota is only 52.45.)

The evident bias of Jefferson's method ultimately led to its abandonment in 1840, when it was replaced by a method first proposed by the great orator Daniel Webster in 1832. Like Jefferson, Webster began with a common divisor d, but instead of dropping the fractional part of the quotients he argued that they should be rounded in the usual way: above one-half up, below one-half down. As in the case of Jefferson's method there always exists a range of divisors that apportions the required number of seats and does so in a unique way (barring ties).

The methods of Webster and Hamilton were used off and on until 1900, when Webster's approach definitively replaced Hamilton's. The reason was the bizarre behavior of Hamilton's method when the house size changed. In the 1880s, for example, an increase in the house size from 299 to 300 seats would have caused Alabama's allotment to decrease from 8 seats to 7. This so-called "Alabama paradox" led Congress to abandon Hamilton's method — thus showing that intuitive mathematical principles can, at least occasionally, play a role in politics.

It could be objected that, in recent times, the house size has been fixed at 435, and thus the Alabama paradox is no longer relevant. But Hamilton's method also displays unacceptable behavior when the house size is fixed and the populations change. In particular, a state that is gaining population can give up seats to a state that is losing population, a phenomenon known as the "population paradox." For both of these reasons Hamilton's method is unacceptable.

But are there any methods that do better? In fact, there is a large class of methods, of which Jefferson's and Webster's are particular examples, that avoid both paradoxes. All of them are based on the principle of the common divisor invented by Jefferson. To explain how they work, consider a set of state populations $p_1, \ldots, p_n$ and a house size h. Choose a *common divisor* d and let $q_i(d) = p_i/d$ be the *quotient* of each state i. Next select a *rounding threshold* r(a) between every pair of successive nonnegative integers a and a + 1. If i's quotient falls in the interval $a \le q_i(d) \le a + 1$ and it exceeds r(a) round it up, otherwise round it down. Finally, adjust the value of d until the rounded numbers sum to h. Each choice of rounding thresholds defines a *divisor method*.

These methods can be justified in two different ways. On the one hand they are the only ones that avoid the Alabama and population paradoxes. On the other hand, each can be shown to optimize an objective function subject to the constraint that the allocations add up to h and are integer-valued. (In fact, d is the Lagrange multiplier associated with the adding-up constraint.)[2]

Five divisor methods have played an important role in US apportionment debates: three were proposed by famous statesmen (Jefferson, Webster, and John Quincy Adams) and two by scientists (Joseph Hill, a statistician at the Census Bureau, and James Dean, a professor at Dartmouth). The dates they were proposed, and the associated rounding thresholds that define them, are shown below.

Five Divisor Method Proposals

	Jefferson	Webster	Hill	Dean	Adams
	(1792)	(1832)	(1911)	(1832)	(1832)
r(a):	a + 1	a + 1/2	$\sqrt{a(a+1)}$	a(a + 1)/(a + 1/2)	a

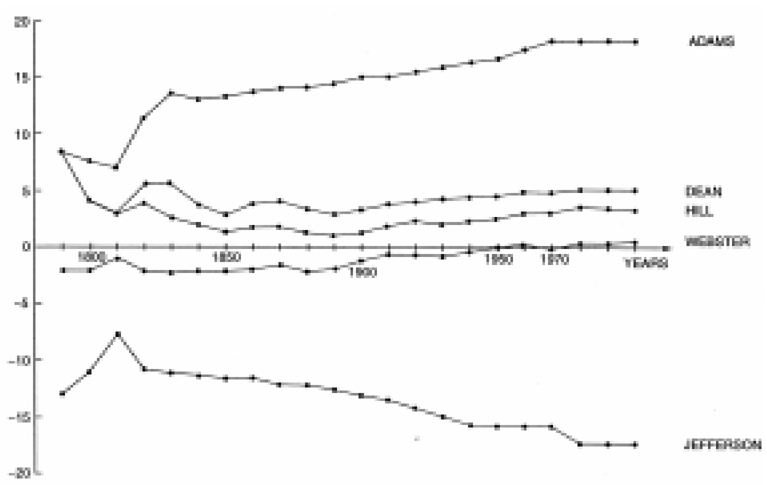
The methods are arranged from left to right so that the rounding thresholds are in descending order: $a + 1 > a + 1/2 > \sqrt{a(a + 1)} > a(a + 1)/(a + 1/2) > a$. Webster rounds at the arithmetic mean, Hill at the geometric mean, and Dean at the harmonic mean. (Jefferson always rounds down, Adams always rounds up.) This ordering has the following implication: consider any two such methods, M and M', and suppose that M lies to the left of M'. If M and M' yield different solutions, then necessarily M gives *more seats to larger states and fewer seats to smaller states* as compared to M'.

History shows that in fact Jefferson's method strongly favors large states, while Adams's method is biased toward small states. The crucial question is whether any method treats small and large states even-handedly. To examine this question empirically, let us evaluate solutions by each of the five methods in each of the twenty-two censuses from 1790-2000. In each census year we first omit the very small states with quota less than one-half, since these must get one seat in spite of their size. Then we divide the remaining states into three categories: large, middle and small, with the middle category taking up the slack if the number of states is not divisible by three. For each method and each census year, we compute the per capita representation in the large states as a group and in the small states as a group. The percentage difference between the two is the method's *relative bias toward small states* in that year. Finally, to estimate their long-run behavior, we compute the average bias of each method up to that point in time. The results are shown in the accompanying graph.

Only Webster's is close to being unbiased; in particular the current method (Hill's) systematically favors the small states by 3-4%. These results can be verified rigorously under various assumptions about the probabilistic distribution of populations.

Given these findings, it is remarkable that the current method was adopted in part because some of the country's leading mathematicians – including John von Neumann, Marston Morse, and Luther Eisenhart — claimed that it was unbiased. Indeed in an NAS report to Congress they claimed that Hill's method is to be preferred because it "stands in a middle position as compared with the other methods." (It was fortunate for this reasoning that they were considering an *odd* number of methods.) Theoretical calculations, buttressed by empirical evidence (which was not considered by the mathematicians), show that on the contrary Hill's method is biased and Webster's is not.

Cumulative Average Bias of Five Traditional Methods, 22 US Censuses



Note: On each curve the point at any census year is the average of the percentage biases of the apportionments of the corresponding method up to and including that year. The number of seats allocated is the actual number that was apportioned. Any state with quota less than .5 is ignored. The remaining states are divided into thirds: large, middle, and small, the "middle" third being slightly larger if the number is not divisible by three. The bias percentage is the percentage by which the small states' representation per capita differs from that of the large states.

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Of course, politics also played a role in the outcome, as it always has: the switch from Webster's to Hill's method in 1941 gave one more seat to Arkansas and one less to Michigan, which essentially guaranteed one more seat for the Democrats (the majority party). It is also true, however, that the scientific arguments bolstered the Democrats' case. Indeed, apportionment debates over the years exhibit an interplay between political and mathematical logic. Jefferson's method was ultimately rejected because of large-state bias, Hamilton's because of bizarre behavior when the house size grew. Changes in method had to wait, however, for the underlying problem to be articulated and for the votes to be in place.

This time around Hill's method happens to give the same solution as Webster's. It might be a propitious moment to correct the situation: no state will be affected now, but the large states can expect to gain in the future. Moreover, the large states have the votes, because in matters pertaining to apportionment, the Senate generally defers to the House, where the large states enjoy a comfortable majority.

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[1]For a detailed account of the history and mathematics of apportionment see M. L. Balinski and H. P. Young, *Fair Representation*, 2nd edition, The Brookings Institution, Washington, D.C., 2001.

[2]H. P. Young, *Equity In Theory and Practice*, Princeton University Press, 1994, pp.188-9.