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 there 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

Nuclear physicists have demonstrated that the material essence of the universe at a time mere microseconds after the big bang consisted 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 forces that eventually formed protons and neutrons 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 capture 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 crashed 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 “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 many gold-gold smashups as many as 10,000 new particles are born of that fireball.

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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, a class of neutron star possessing a gigantic magnetic field. Such “magnets” 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 time delay scopes 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.nasa.gov/pr/2005/vyburst/; many telescopes participated in the observations, reports appeared in the 28 April 2005 issue of Nature.)

THE BIGGEST SPLASH OF LIGHT FROM OUTSIDE THE SOLAR SYSTEM

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 “magnets” 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.

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DIRECT DETECTION OF EXTRASOLAR Planets

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, orbiting the star 61 Virigins (153 light years away), the other TREs-I (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 near-record-breaking accuracy (2×10-24 gram) for the first time. In experiments, the presence of xenon 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 microbristors 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 can filter signals in cell phones. When heated, a pyroelectric crystal polarizes, generating a significant amount of electric charge near a surface, leading to a very large electric field effect. This can accelerate ions to relativistic kinetic 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 (LiTaO3) pyroelectric crystal so that one of its faces touches a copper plate. The researchers 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/μm) that it strips electrons from nearby deuterium atoms. Repelled by the positively charged tip, and crystal ions, the probe accepts the electrons and the deuterium ions fuse with the crystal ions, the resulting deuterium ions then accelerate towards a solid target of erbium deuteride disc which itself is surmounted by a tungsten probe. They cool and then heat the crystal, thereby producing a series of high-energy fusion events.

By using electrons that have been spin polarized—the weak force can be studied by looking at how they are scattered from electrons bound to hydrogen atoms in a stationary target. This approach can involve 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. The cross section for scattering from the ground state to the excited state is 5.9 barns, which is consistent with the prediction of the model used in the experiment. By using this approach, the weak force can be studied in detail.

Geoneutrinos detect very low fluxes and interact rarely, but are made in large numbers inside the sun as a byproduct of fusion reactions. They are also routinely measured 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 neutrinos.

New, 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) has reported the presence of electron antineutrinos from radioactive decays. The uncertainty in the model of the Earth’s interior makes the exact number vague, but it might be dozens of geo-neu’s.

Neutrinos presumably come from the decays of U-232 or Th-232. They are seen through the two beta-decay modes of each isotope. The electron antineutrino signal is seen through the two beta-decay modes of each isotope. The electron antineutrino signal is seen in the Kamioka detector when a high energy electron antineutrino is scattered off a nucleus in the detector.

APPLICATIONS OF NEUTRINOS

Neutrinos have been used in many applications, including in high energy physics experiments and in the study of the Earth’s interior. They are also being used in medical research, such as in the treatment of cancer. In addition, neutrino oscillations can be used to study the properties of neutrinos, which can provide insights into the fundamental nature of matter and energy.

MAGNETIC FIELD CRITICAL TEMPERATURE OF SUPERCONDUCTORS

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 field—a Feshbach resonance—between the atoms. But molecules made that way are only feebly attached. By using the process of photoassociation to fuse two atoms into one molecule, researchers have made a new, deep bound molecule that is stable. 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 created using the two lasers. 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, the two molecules can be formed from the two laser beams 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 of the carbon atom 1s-2s transitions. The force between a BEC of atoms and molecules is attractive. In their experiments, the 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. 96, 052002, 2005).
**HOW EFFECTIVE WILL FLU VACCINE BE?**

How effective will this year's flu vaccine be? 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 viruses 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 better reflect the vaccine’s ability to protect against 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 output of these two different “detection” epitopes. 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. PNNL researchers are the first to observe this effect. The novel hydrophobic propensity helps to shape itself, the water-substrate bond has to be strong enough to form a stable monolayer. Weak water bonds result in a “classic” hydrophobic state, in which the water merely balls up immediately; in other words, not even a first monolayer of ice forms. However, a water-substrate bond strong enough to prevent balling also prevents water molecules from becoming mobile enough to begin forming into tiny islands of two-dimensional ice. At lower temperatures, all of the water in the substrate will fall off the edges into the spaces between the islands. In this way the water surface becomes ice over completely with a monolayer.

But because the water molecules’ four bonds are now spoken for (1 to the Pt substrate at the island’s edge, 2 to other water molecules at the island’s center, 3 to 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 propensity to show itself, the water-substrate bond has to be strong enough to form a stable monolayer. Weak water bonds result 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 can have a great deal 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, 161102, 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 G. 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 Optics and Quantum Electronics, 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 “noize,” jittery and random fluctuations of light. This in turn drives the precision limits on the limits of measuring light, as well as 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 developed a technique for measuring the speed of light. This in turn drives the limits on the limits of measuring light, as well as the as understanding of optical detectors that count single photons at a time. Single-photon detectors are important for applications such as quantum cryptography.

**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 splits 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 arrange the entanglement of any two members of the pair, independent of where the photons are produced. 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 to multiple photons (bits of light) to be encoded in a single pair of entangled photons. 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, 263001, 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 normal materials (for example, a normal material’s conductivity decreases as it becomes more electrified), an entire wave can travel in one direction down a waveguide. This in turn drives the precision limits on the limits of measuring light, as well as the as understanding of optical detectors that count single photons at a time. Single-photon detectors are important for applications such as quantum cryptography.

This near-field optics are not suitable for such applications as reading glasses or telescopes. External magnetic force, the charge carriers can detect and process images in the presence of 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 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 avoiding mutagenic mistakes. The researchers have created a system to detect and monitor the ability of RecA to attract and assemble nucleic acid single-stranded DNA into functional helical phage. When the double-helix DNA is seriously damaged, single-stranded DNA is exposed and RecA helps to repair the damage.

**ENERGY INTO DIRECTED MOTION**

Light energy can tilt the world of magnetic materials so that, under the right conditions, the magnetic moments rotate in a direction determined by the light. (Kwon et al. Science 311, 229, 2006)

**PARTICLES OF HEAT**

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

In the electrical Hall effect, when an electrical current is being driven by an electric field is subjected to an opposing magnetic field, the magnetic 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 photons, which are vibrations rippling through the lattice 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 MPS-CNRS researchers felt, however, that in a magnetic field of photons 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 Celsius at one side, creating the thermal equivalent of an applied voltage. Application of a magnetic field of a few Tesla led to an extreme small (smaller than one thousandth of a degree), yet detectable temperature difference. (Strohm et al., Phys. Rev. Lett. 95, 155901, 2005)

**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 and his colleagues at the University of California at Riverside, guided by theorist Talat Rahman and his colleagues at the University of California at Riverside, guided by theorist Talat Rahman substantial advance in understanding the fundamental processes such as UV radiation can be detected and processed and crucial role in maintaining the integrity of DNA.

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 normal materials (for example, a normal material’s conductivity decreases as it becomes more electrified), an entire wave can travel in one direction down a waveguide. This in turn drives the precision limits on the limits of measuring light, as well as the as understanding of optical detectors that count single photons at a time. Single-photon detectors are important for applications such as quantum cryptography.

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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 process in which kinetic proofreading and assembly fluctuations are combined (Thyss et al., Physical Review Letters, 17 Dec. 2004, Phys. Rev. Lett. 93, 238103 (2004)).

Meanwhile, researchers at the University of Texas (Kevin Dorfman and Jean-Louis Fouay) 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 disperses toward 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 energies of the oscillating paddles are quantized, and this in turn should show up as a. (Gaidarzhy et al., Phys. Rev. Lett. 94, 030402, 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. Moreover, the light pulse 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 light on the sample and then recording the light scattered from the BEC. The excited electrons are imaged in a negative manner: the paddles can travel out to certain displacements from a heat sink, seem to oscillate together in a peculiar manner: the paddles can travel out to certain displacements but not to the others. The setup for this experiment consists of a lithographically prepared structure looking like a doubled-sided comb.

Next, a gold-film electrode is deposited on top of the spin. Then a laser pulse, which is sent through the magnetic field, hits the paddle and the electrons are excited. The laser pulse is then stopped and the paddle comes to rest as the magnetic field is applied. This sets the structure to vibrate at frequencies as high as one gigahertz. This makes the single electrons in the paddle 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 slice of electric charge. Now a new experiment has found evidence of a second resonance at 40 eV. This second type of collective excitation is called a "volume plasmon" since the shape of the collective electron ensemble is thought to oscillate 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, 065403, 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 with atoms that have been able to load the atoms into the crystal lattice 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 loaded in their specified sites can now guide to interatomic collisions in the lattice 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 opens up this setup to the study of various condensed matter physics, such as those that strive to explain high-temperature superconductivity, on a real physical system. (Kohl et al., Phys. Rev. Lett. 94, 080403, 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 pillars, each a few atoms thick, are brought into contact with a heat sink, seem to oscillate together in a peculiar manner: the paddles can travel out to certain displacements but not to the others. This setup for this experiment consists of a lithographically prepared structure looking like a doubled-sided comb.

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**NIQUEL-78, THE MOST NEUTRON-RICH OF THE DOUBLY- MAGNUS NICEL**

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” (standing for random) unfolding inside the explosion, a succession of nuclei build up on the many available neutrons. The energetic collision of a neutron or even a photon with a free proton in the explosion means that the 2-GHz clock (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 PHOTONIC WAVEGUIDE

A new kind of photonic 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 photonics must also produce devices that are faster and lower in energy scale, than the present semiconductor approaches. One attractive direction for such devices is to use the natural atomic control of light in a medium for optical applications. This control is provided by the fact that light is a wave with a momentum that is proportional to the index of refraction n, and that this wave moves with a speed v = c/n, where c is the speed of light. Thus, a beam of light in a low-index medium moves more slowly than the same beam in a high-index medium. This reality is the key to an important new optical device that may soon bring a new generation of optical circuits to market.

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 momenta were measured provided new insight into the refractive index and into the atom’s motion. The MIT team discovered that the momentum of a photon equals h/λ, where h is Planck’s constant and λ is the wavelength of the light. In a dispersive medium, the index of refraction depends on the wavelength, so the momentum of a photon must depend on the wavelength as well. The MIT team’s result has allowed them to make a new measurement of the atom’s motion and to correct an error in the refractive index of a gas.

The team measured the momentum of an atom in an experiment that used a dilute gas as a medium. The experimenters used a laser beam tuned to a specific frequency to excite an atom to a higher energy state. The atom then emitted a photon that was detected by a photodetector. The momentum of the photon was measured by the change in momentum of the atom, which was detected by a position-sensitive detector. The momentum of the photon was found to be proportional to the index of refraction of the gas, which is why the team was able to make a new measurement of the index of refraction.

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external magnetic field opposed to the prevailing magnetic orientation of the crystal can cause a sudden reversal of spins of the molecules. The reverse 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 a case of 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 "front" is the motion 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 the existence of our dimensionality, namely three spatial dimensions. 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 by the way our universe was created. To "see" these extra dimensions, they point out, is like trying to see a three-dimensional object by viewing it from a direction perpendicular to one of its dimensions. But in our universe, the "gravity" apparently a 3D object in a 1D universe? Why not a 4D object or some dimensionality?

In the present paper, Karch and Randall show that the cosmic evolution of the 10D universe produces a state of de Broglie matter, results in an under-populated chaffly 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 proton and a neutron swells away from the rest of the nucleus to form a separate island in its unexcited state, a typical atomic nucleus consists of a number of constituent neutrons and protons boiling 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 into motion and a secondary target of lead. The excited states later disintegrate as 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 shell of protons and neutrons. (Atkins et al., Phys. Rev. Lett. 95, 251103, 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 only 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 for atoms with more than one electron (for example, for lithium, for which a high-resolution infrared spectrum of NO in fluids could be recorded for the first time). This has been observed before in the gas phase, but never before has such a high resolution spectrum been seen in the helium environment. (Haeften et al., Phys. Rev. Lett. 95, 213003, 2005)

GUIDED SLOW LIGHT

Guided, slow light in an ultracold medium has been demonstrated by Mukund Vengalattore and Mara Prentiss at Harvard. Slow light pulses in a sample of atoms had been accomplished before by slowing light with 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 quality comes 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, depression, and these emissions are then reemitted by the far field of a pump laser beam. Furthermore, the probe beam can be amplified or attenuated depending on the degree of dispersion in the atoms. This process can be used as a switch for light or as a waveguide.

The "two-loop term" at high energies (Suzuki 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—are observed to have originated in the plane of our home galaxy. These photons often are correlated with the gas and stars at the height of the Milky Way plane. They are thought to be originating from the very hot (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, a 70,800 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 Flesyher of New York University, are consistent with the instantaneous cosmic ray flux in this region.

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 higher energies. (Atkins et al., Phys. Rev. Lett. 95, 251103, 2005)

QUANTUM SOLVENT

Scientists at the Ruhr-Universitat 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 radiative molecule (tomewhere) which some resonance chemistry as a unit. To the best of 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 xenon at a temperature of about 0.4 Kelvin, it spins freely. The helium acts as a solvent for the NO 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)