Controlling Elasticity with Magnetism

The University of Nebraska-Lincoln physicist has found that, under certain conditions, the magnetic properties of a material can predict the relationship between its elasticity and temperature. [22]

Materials Science and Engineering Ph.D. students Price Pellegren and Derek Lau, led by Assistant Research Professor of Materials Science & Engineering Vincent Sokalski, demonstrate that this stiffness is precisely what governs how the domain wall moves around in certain ultrathin magnets. [21]

Liquid electrolytes are essential components in a variety of emerging energy technologies, including batteries, supercapacitors and solar-to-fuel devices. [20]

Basic processes in chemistry and biology involve protons in a water environment. [19]

Scientists from the QUEST Institute at the Physikalisch-Technische Bundesanstalt (PTB) have now presented a model system that allows the investigation of atomic-scale friction effects and friction dynamics that are similar to those taking place in proteins, DNA strands and other deformable nanocontacts. [18]

New research could make lasers emitting a wide range of colors more accessible and open new applications from communications and sensing to displays. [17]

A novel way to harness lasers and plasmas may give researchers new ways to explore outer space and to examine bugs, tumors and bones back on planet Earth. [16]

A team of researchers at Harvard University has successfully cooled a three-atom molecule down to near absolute zero for the first time. [15]

A research team led by UCLA electrical engineers has developed a new technique to control the polarization state of a laser that could lead to a new class of powerful, high-quality lasers for use in medical imaging, chemical sensing and detection, or fundamental science research. [14]

UCLA physicists have shown that shining multicolored laser light on rubidium atoms causes them to lose energy and cool to nearly absolute zero. This result suggests that atoms fundamental to chemistry, such as hydrogen and carbon, could also be cooled using similar lasers, an outcome that would allow researchers to study the details of chemical reactions involved in medicine. [13]

Powerful laser beams, given the right conditions, will act as their own lenses and "self-focus" into a tighter, even more intense beam. University of Maryland physicists have discovered that these self-focused laser pulses also generate violent swirls of optical energy that strongly resemble smoke rings. [12]

Electrons fingerprint the fastest laser pulses. [11]

A team of researchers with members from Germany, the U.S. and Russia has found a way to measure the time it takes for an electron in an atom to respond to a pulse of light. [10]

As an elementary particle, the electron cannot be broken down into smaller particles, at least as far as is currently known. However, in a phenomenon called electron fractionalization, in certain materials an electron can be broken down into smaller "charge pulses," each of which carries a fraction of the electron's charge. Although electron fractionalization has many interesting implications, its origins are not well understood. [9]

New ideas for interactions and particles: This paper examines the possibility to origin the Spontaneously Broken Symmetries from the Planck Distribution Law. This way we get a Unification of the Strong, Electromagnetic, and Weak Interactions from the interference occurrences of oscillators. Understanding that the relativistic mass change is the result of the magnetic induction we arrive to the conclusion that the Gravitational Force is also based on the electromagnetic forces, getting a Unified Relativistic Quantum Theory of all 4 Interactions.

Author: George Rajna

Physicist points way to controlling elasticity with magnetism

If Plastic Man, Elastigirl or Mr. Fantastic ever encounter Magneto, they'd better hope the iconic X-Men figure hasn't read the latest research from Christian Binek.

The University of Nebraska-Lincoln physicist has found that, under certain conditions, the magnetic properties of a material can predict the relationship between its elasticity and temperature.

His finding may point the way toward controlling the elasticity of certain materials by designing their magnetic properties or applying a magnetic field to them. Given the ease with which magnetic fields can now be manipulated, Binek said, that could eventually mean tailoring elasticity with the mere press of a button or turn of a knob.

In the meantime, knowing that magnetism alone can predict how elasticity will respond – or not respond – to changes in temperature might help engineers better select or design materials for specific purposes.

Binek cited the 1986 disintegration of the Challenger space shuttle as a prominent example of elasticity's importance in engineering design. The hardening and failure of an elastic O-ring on Challenger's rocket booster – a consequence of cold temperatures – ultimately caused the shuttle to break apart, killing its seven crew members.

"So you can find materials that do not change elastic properties with temperature," said Binek, professor of physics and astronomy. "You may find materials that change with temperature at will. And you may find materials where you can, at a given temperature, change the elastic properties by an external control."

Thermodynamic duo

The laws of thermodynamics describe the relationships among many factors – temperature, entropy, volume, pressure – that affect how heat gets converted into other forms of energy. And it's long been known that these laws encompass the properties of magnetism and elasticity.

But by deriving a new formula from existing ones, Binek managed to show that the elasticity-temperature relationship is basically encoded in the magnetism of a material.

Binek's formula does have limitations. For now, it applies only if a material's magnetic behavior changes linearly with the magnetic field being applied to it. Likewise, the material's elasticity has to be linear, meaning that the amount of strain it exhibits has to be constantly proportional to the amount of physical stress being exerted on it.

Even so, the formula applies to materials featuring various forms of magnetism. That includes the form technically found in every material: diamagnetism, which describes a tendency to repel magnetic fields so weakly that it goes unnoticed without specialized instruments.

Superconductive materials – those that feature no resistance to electricity – display a pronounced form of diamagnetism below a critical temperature, at which point they begin completely repelling magnetic fields. Below that temperature threshold, Binek found something remarkable: The elasticity of superconductors no longer responds to temperature changes. That phenomenon held when he performed calculations for both ceramic and single-crystal superconductors, which have substantially different microscopic surfaces and atomic structures.

"My (mathematical) expression makes no claims about the material," Binek said. "It's very general. It only says: If the susceptibility (to magnetism) is constant, then the elastic property should be constant. If that is so, nothing else (about the superconductor) should matter, which is honestly a little difficult to believe.

"You wonder: How can something like an elastic property, which surely depends on structural details, be independent of anything related to the structure? But then you go to the (scientific) literature, apply your formula, and you find that, yes, it is correct."

The elastic-magnetic formula also applies to materials for which magnetic fields induce a weak attraction known as paramagnetism. And ferromagnetic materials – those strongly attracted to magnetic fields and usually synonymous with the term "magnetic" – obey Binek's formula above a certain temperature threshold that makes them behave more like their paramagnetic cousins.

Binek said the formula might even work for ferroelectric materials, whose alignment of positive and negative charges, or polarization, can be reversed by an electric field. Ferroelectricity facilitates the storage of electrical energy, making it useful in devices ranging from capacitors to random-access memory.

"Rather than tuning the elastic properties by a magnetic field, you may be able to tune them by electric fields," he said. "Technologically, that could be even more interesting.

"There are certainly many applications that one could think of, and I think many of them can be useful. I hope this is not the end of the story, but rather the beginning." [22]

Uncovering the connection between negative stiffness and magnetic domain walls

Nature doesn't like having interfaces—this is why bubbles like to be round, and the surface of a pond settles to flat as long as it's not disturbed. These trends minimize the total amount of interface (or surface) that is present. As an exception to this behavior, certain materials are known to have a property, called negative stiffness, where the interface prefers to become distorted, or wavy, even without any external stimulation.

Interfaces with negative stiffness have been considered in crystals before, but the characteristic has now also been found in modern magnetism. Researchers in Carnegie Mellon University's College of Engineering have shown that the interface separating two oppositely magnetized regions of a material (called a domain wall) can also exhibit negative stiffness.

Materials Science and Engineering Ph.D. students Price Pellegren and Derek Lau, led by Assistant Research Professor of Materials Science & Engineering Vincent Sokalski, demonstrate that this stiffness is precisely what governs how the domain wall moves around in certain ultrathin magnets.

In the study, they also describe how the domain wall can be adopted as a tool to measure the distribution of unwanted defects in the material.

This understanding of domain wall behavior is critical for the development of future energy-efficient computers where information is stored in the domain wall as it moves through a magnetic circuit.

For more information on this research, please read the full article, "Dispersive Stiffness of Dzyaloshinskii Domain Walls," published in Physical Review Letters. [21]

Scientists explore electronic properties of liquid electrolytes for energy technologies

Liquid electrolytes are essential components in a variety of emerging energy technologies, including batteries, supercapacitors and solar-to-fuel devices.

"To predict and optimize the performance of these devices, a detailed understanding of the electrolytes, particularly their electronic properties such as the ionization potential and electron affinity, is critical," said Anh Pham, a Lawrence Livermore National Laboratory (LLNL) Lawrence Fellow in the Quantum Simulations Group, and the lead author of a paper in the June 23 edition of Science Advances.

As an example, Pham pointed to how proper energy alignment at the electrode-electrolyte interface of photoelectrochemical (PEC) cells is key to achieving efficient hydrogen production.

Pham, along with LLNL researcher Eric Schwegler, Robert Seidel and Steven Bradforth from the University of Southern California, and Marco Govoni and Giulia Galli from the Argonne National Laboratory and the University of Chicago, have presented an experimentally validated simulation strategy for computing the electronic properties of aqueous electrolytes.

The team directly simulated and measured the electronic excitation of various solvated ions in liquid water. By combining first-principles molecular dynamics simulations with state-of-the-art electronic structure methods, the team could predict the excitation energies of the solvents and solutes, such as the ionization potentials of the solvated ions. The team also demonstrated that the coupling of this theoretical framework with advanced spectroscopy techniques provides a powerful tool for the identification of chemical species and reactions that occur in solutions.

The new method opens up the possibility to predict the electronic response in complex electrolytes for a range of applications. For example, the research provided a theoretical foundation for understanding and engineering the electronic properties of liquid electrolytes in PEC cells for hydrogen production and ionic liquid for batteries.

"The proposed computational framework is general and applicable to non-metallic liquids, offering great promise in understanding and engineering solutions and liquid electrolytes for a variety of important energy technologies," Pham said.

In a broader sense, the new simulation capability represents the first step toward a unified method for the simulation of realistic, heterogeneous interfaces in electrochemical systems. [20]

Ultrafast motions and fleeting geometries in proton hydration

Basic processes in chemistry and biology involve protons in a water environment. Water structures accommodating protons and their motions have so far remained elusive. Applying ultrafast vibrational spectroscopy, researchers have mapped fluctuating proton transfer motions and provided direct evidence that protons in liquid water are predominantly shared by two water molecules. Femtosecond proton elongations within a hydration site are 10 to 50 times faster than proton hopping to a new site, the elementary proton transfer step in chemistry.

The proton, the positively charged nucleus H+ of a hydrogen atom and smallest chemical species, is a key player in chemistry and biology. Acids release protons into a liquid water environment where they are highly mobile and dominate the transport of electric charge. In biology, the gradient of proton concentration across cell membranes is the mechanism driving the respiration and energy storage of cells. Even after decades of research, however, the molecular geometries in which protons are accommodated in water and the elementary steps of proton dynamics have remained highly controversial.

Protons in water are commonly described with the help of two limiting structures (Fig. 1A). In the Eigen complex (H9O4+) (left), the proton is part of the central H3O+ ion surrounded by three water molecules. In the Zundel cation (H5O2+) (right), the proton forms strong hydrogen bonds with two flanking water molecules. A description at the molecular level employs the potential energy surface of the proton (Fig. 1B) which is markedly different for the two limiting geometries. As shown in Fig. 1B, one expects an anharmonic single-minimum potential for the Eigen species and a double minimum potential for the Zundel species. In liquid water, such potentials are highly dynamic in nature and undergo very fast fluctuations due to thermal motions of surrounding water molecules and the proton.

Researchers from the Max Born Institute in Berlin, Germany, and the Ben Gurion University of the Negev in Beer-Sheva, Israel, have now elucidated the ultrafast motions and structural characteristics of protons in water under ambient conditions. They report experimental and theoretical results in Science which identify the Zundel cation as a predominant species in liquid water. The femtosecond (1 fs = 10-15 s) dynamics of proton motions were mapped via vibrational transitions between proton quantum states (red and blue arrows in Fig. 1B). The sophisticated method of two-dimensional vibrational spectroscopy provides the yellow-red and blue contours in Fig. 2A that mark the energy range covered by the two transitions. The blue contour occurs at higher detection frequencies than the red, giving the first direct evidence for the double-minimum character of the proton potential in the native aqueous environment. In contrast, the blue contour is expected to appear at smaller detection frequencies than the red one.

Water makes the proton shake

The orientation of the two contours parallel to the vertical frequency axis demonstrates that the two vibrational transitions explore a huge frequency range within less than 100 fs, a hallmark of ultrafast modulations of the shape of proton potential. In other words, the proton explores all locations between the two water molecules within less than 100 fs and very quickly loses the memory of where it has been before. The modulation of the proton potential is caused by the strong electric field imposed by the water molecules in the environment. Their fast thermal motion results in strong field fluctuations and, thus, potential energy modulations on a sub-100 fs time scale. This picture is supported by benchmark experiments with Zundel cations selectively prepared in another solvent and by detailed theoretical simulations of proton dynamics (Fig. 2B).

A specific Zundel cation in water transforms into new proton accommodating geometries by the breaking and reformation of hydrogen bonds. Such processes are much slower than the dithering proton motion and occur on a time scale of a few picoseconds. This new picture of proton dynamics is highly relevant for proton transport by the infamous von Grotthuss mechanism, and for proton translocation mechanisms in biological systems. [19]

Laser-cooled ions contribute to better understanding of friction

In physics, it is useful to know as precisely as possible how friction phenomena arise—and not only on the macroscopic scale, as in mechanical engineering, but also on the microscopic scale, in areas such as biology and nanotechnology. It is quite difficult to study friction at the atom scale where non-linear effects prevail.

Scientists from the QUEST Institute at the Physikalisch-Technische Bundesanstalt (PTB) have now presented a model system that allows the investigation of atomic-scale friction effects and friction dynamics that are similar to those taking place in proteins, DNA strands and other deformable nanocontacts. This model system consists of laser-cooled ions that arrange themselves in Coulomb crystals. The researchers have carried out experiments and numerical simulations and obtained new fundamental findings on friction processes in these atomic systems. They have now presented their results in the scientific journal Nature Communications.

Most macroscopic objects have a rough texture from an atomic view point. Even if they feel smooth to the touch, they exhibit asperities. Strictly speaking, two objects never lie directly on top of each other, but only touch each other at these asperities. The atomic lattice structure therefore plays no role in this interaction. This is quite different for objects on the atomic scale, like nanomachines or biomolecules. "Here, atomically smooth surfaces touch each other. The surface therefore also plays a role and must be taken into account in model calculations," explains PTB physicist Tanja E. Mehlstäubler. "These models also explain fascinating phenomena such as superlubricity, where static friction becomes nearly nonexistent. It occurs when two crystalline surfaces are incommensurate to each other. This means that the ratio of the lattice spacings of the sliding surfaces is irrational. This leads to there being no place where the two surfaces are an exact match for each other."

There are thus enough reasons to precisely measure friction at the nanoscale and to investigate its dynamics. A powerful instrument already exists for measuring friction, the friction force microscope. "Direct experimental access to the dynamics of a friction system is nearly impossible. Model systems in which the atoms are easily controlled—both temporally and spatially— are therefore indispensable. This allows us to investigate them," explains Mehlstäubler. Such a system has now been presented by the scientists from PTB, together with their partners from Sydney. Ytterbium ions kept in an ion trap are cooled by means of lasers to such an extent (down to a few millikelvins) that they form a crystal consisting of two chains. The ions arrange themselves in such a way that the nearest neighbor is always as far away as possible. This structure is called a zigzag.

Two such ion chains are a very accurate representation of the two partners of a friction process—and they are easy to observe very precisely. When ytterbium ions are irradiated with light whose frequency is close to their resonant frequency, they begin to fluoresce. "We are thus able to observe the individual atomic particles in their motion through our imaging optics," adds Jan Kiethe, a physicist at PTB and the main author of the study. A transition between two different phases, which was caused by the presence of a structural lattice defect, has been observed and analyzed here. In one of the regimes, static friction is the main actor in the transport dynamics; in the other regime, it is sliding friction.

The dynamics of the ion chains are comparable to those of molecule chains like DNA. In their study, the scientists have created a physical model system to investigate the complex dynamics of friction in 1-D, 2-D and 3-D systems with atomic precision. Moreover, this model system has paved the way for the investigation of transport phenomena in the quantum regime. [18]

New organic lasers one step closer to reality

New research could make lasers emitting a wide range of colors more accessible and open new applications from communications and sensing to displays.

Researchers at Kyushu University's Center for Organic Photonics and Electronics Research (OPERA) reported an optically pumped organic thin-film laser that can continuously emit light for 30 ms, which is more than 100 times longer than previous devices.

Unlike the inorganic lasers commonly found in CD drives and laser pointers, organic thin-film lasers use a thin layer of organic molecules as the laser medium, which is the material in the device that actually produces lasing by emitting and amplifying light when excited with an energy source. In this case, the energy source was intense ultraviolet light from an inorganic laser.

A very promising feature of organic thin-film lasers is the possibility to more easily achieve colors that are difficult with inorganic lasers. By designing and synthesizing molecules with new structures, emission of any color of the rainbow is possible.

"People have been studying organic thin-film lasers for a long time, but degradation and loss processes have greatly limited the duration of emission," says Atula S. D. Sandanayaka, lead author of the paper in Science Advances reporting the new results.

The researchers were able to reduce these problems and extend the duration of the lasing by combining three strategies.

To reduce major losses originating from the absorption of laser emission by packets of energy - called triplet excitons - that build up in the organic laser medium during operation, the researchers found an organic laser medium with triplet excitons that absorb a different color of light than that emitted by the laser.

Thermal degradation caused by heating of the lasers during operation was reduced by building the devices on a crystalline silicon wafer and gluing a piece of sapphire glass on top of the organic laser medium with a special polymer.

The silicon and sapphire, which are good heat conductors, help to quickly remove heat from the devices while at the same time encapsulating them.

Finally, through optimization of a frequently used grating structure - called a mixed-order distributed feedback structure - placed under the organic laser medium to provide optical feedback, the input energy needed to operate the lasers was reduced to new lows, further lessening the heating.

"These devices really operate at the extreme, so we have to keep finding new tricks to eliminate any inefficiencies and prevent the devices from burning themselves out," says Professor Chihaya Adachi, director of OPERA.

Using these simple devices in conjunction with inorganic lasers is promising for more easily achieving colors that are difficult to produce using common lasers, with applications in spectroscopy, communications, displays, and sensors.

Development is still ongoing to sustain the emission for even longer durations, but as for what is next?

"Our ultimate goal is realizing organic thin-film lasers that directly use electricity as the energy source, and this is an important step in that direction," says Adachi. [17]

Using lasers to examine space, bugs and bones

A novel way to harness lasers and plasmas may give researchers new ways to explore outer space and to examine bugs, tumors and bones back on planet Earth.

Lawrence Livermore National Laboratory (LLNL) physicist Felicie Albert led an international team pursuing this new regime in laser research, which was described in a Physical Review Letters (PRL) paper published online March 31.

Albert and the team spent more than two years experimenting with new ways to generate X-rays capable of probing the size, density, pressure and composition of highly transient states of matter, such as those found in the cores of planets and in fusion plasmas. Plasmas make up 99 percent of the known universe.

The researchers studied betatron X-ray radiation, emitted when electrons are accelerated to relativistic energies and wiggle in the plasma wave produced by the interaction of a short, intense laser pulse with a gas.

Traditionally, this source has been well studied for laser pulses with femtosecond (quadrillionth of a second)-long durations.To study betatron X-ray emission at the intensities and pulse durations relevant to larger-scale laser facilities, such as LLNL's Advanced Radiographic Capability (ARC) laser, the researchers conducted an experiment on the Titan Laser at the Laboratory's Jupiter Laser Facility. There they observed betatron X-ray radiation driven by much longer, picosecond-duration laser pulses.

"For me a picosecond is forever," Albert joked. While picoseconds measure time in trillionths of a second, that's slow to a researcher who prefers even shorter laser pulses.

The experimental work shows that the new radiation source holds great promise for undertaking applications at international large-scale laser facilities, where it potentially could be used for X-ray radiography and phase contrast imaging of laser-driven shocks, absorption spectroscopy and opacity measurements.

Other LLNL colleagues include Nuno Lemos, Brad Pollock, Clement Goyon, Arthur Pak, Joseph Ralph and John Moody, along with collaborators from the University of California-Los Angeles, the SLAC National Accelerator Laboratory, Lawrence Berkeley National Laboratory, the University of California-Berkeley and the University of Lisbon in Portugal.

Albert noted that the results did not reveal themselves immediately as in some experiments, and that it took the team a lot of analysis and hard work to uncover the new regime.

They note in their paper the wide variety of potential uses of the technology: Betatron X-ray radiation driven by short-pulse lasers has been used for biological and medical purposes, such as X-ray phase contrast imaging of insects and hard X-ray radiography of bone. Its unique properties also make it suitable for studying the dynamics of high-energy-density plasmas and warm dense matter - a state near solid densities - and temperatures found in the cores of giant planets like Jupiter and in inertial confinement fusion plasmas. [16]

Laser cooling a polyatomic molecule

A team of researchers at Harvard University has successfully cooled a three-atom molecule down to near absolute zero for the first time. In their paper published in Physical Review Letters, the team describes how they achieved the feat and suggest that their technique could be modified to allow for cooling molecules with even more atoms.

For many years, scientists have been laser cooling atoms down to near absolute zero as part of research into understanding how atoms work—the cooler temperatures slow things down, allowing for a better look. In such work, atoms are cooled due to scattering of photons, which serves to transfer momentum—electron bonds are forced to release the photons, causing the atoms to nearly cease moving. Doing the same has been harder for molecules because of their more complicated structure, i.e., their vibrational and rotational degrees of freedom.

A specific type of laser cooling of molecules called Sisyphus cooling involves creating a wave of laser light that causes the molecule to emit into a magnetic state without interaction with the laser—another smaller magnetic field is then used to bring the molecule back to its initial state. The process repeats with each step causing a loss of kinetic energy which causes the molecule to grow cooler and cooler. In this new effort, the researchers used this technique (magnetically assisted Sisyphus laser cooling) to cool a molecule with three atoms down to very near absolute zero.

The molecule (strontium monohydroxide—SrOH) was chosen due to its unique properties—it contains an electron that does not participate very strongly in bonding—which the team notes, made it an ideal candidate. It also suggests, the team further notes, that other molecules with like properties could work, as well—even some with more atoms. They suggest the technique might work with molecules that have as many as 15 atoms, and it could also be used as part of the basis for a quantum computer because it allows for changing a molecular state with precision. It might also prove useful in chemistry, as well, they note, because it could cause reactions to slow down, allowing for better observation, giving a far better level of detail. [15]

Research team develops technique to control laser polarization electronically, with no moving parts

A research team led by UCLA electrical engineers has developed a new technique to control the polarization state of a laser that could lead to a new class of powerful, high-quality lasers for use in medical imaging, chemical sensing and detection, or fundamental science research.

Think of polarized sunglasses, which help people see more clearly in intense light. Polarizing works by filtering visible light waves to allow only waves that have their electric field pointing in one specific direction to pass through, which reduces brightness and glare.

Like brightness and color, polarization is a fundamental property of light that emerges from a laser. The traditional way to control the polarization of a laser was to use a separate component like a polarizer or a waveplate. To change its polarization, the polarizer or waveplate must be physically rotated, a slow process that results in a physically larger laser system.

The team from the UCLA Henry Samueli School of Engineering and Applied Science developed a specialized artificial material, a type of "metasurface," that can tune the laser's polarization state purely electronically, without any moving parts. The research was published in Optica. The breakthrough advance was applied to a class of lasers in the terahertz range of frequencies on the electromagnetic spectrum, which lies between microwaves and infrared waves.

"While there are a few ways to quickly switch polarization in the visible spectrum, in the terahertz range there is currently a lack of good options," said Benjamin Williams, associate professor of electrical engineering and the principal investigator of the research. "In our approach, the polarization control is built right into the laser itself. This allows a more compact and integrated setup, as well as the possibility for very fast electronic switching of the polarization. Also, our laser efficiently generates the light into the desired polarization state—no laser power is wasted generating light in the wrong polarization."

Terahertz radiation penetrates many materials, such as dielectric coatings, paints, foams, plastics, packaging materials, and more without damaging them, Williams said.

"So some applications include non-destructive evaluation in industrial settings, or revealing hidden features in the study of art and antiquities," said Williams, who directs the Terahertz Devices and Intersubband Nanostructures Laboratory. "For example, our laser could be used for terahertz imaging, where the addition of polarization contrast may help to uncover additional information in artwork, such as improved edge detection for hidden defects or structures."

The work is based on the group's recent development of the world's first vertical-external-cavity surface-emitting laser, or VECSEL, that operates in the terahertz range.

Their new metasurface covers an area of 2 square millimeters and has a distinct zigzag pattern of wire antennas running across its surface. An electric current runs through the wires, selectively energizing particular segments of the laser material, which allows a user to change and customize the polarization state as needed. [14]

Physicists use multicolored laser light to study atoms critical to medicine

UCLA physicists have shown that shining multicolored laser light on rubidium atoms causes them to lose energy and cool to nearly absolute zero. This result suggests that atoms fundamental to chemistry, such as hydrogen and carbon, could also be cooled using similar lasers, an outcome that would allow researchers to study the details of chemical reactions involved in medicine.

This research is published online today in the journal Physical Review X.

Physicists have known for several decades that shining laser light of a particular energy onto atoms can decrease their speeds and therefore energy. Small packets of light—photons—carry momentum with them, and this momentum is imparted to atoms as the photons are absorbed. By forcing atoms moving in one direction to absorb only photons traveling in the opposite direction, researchers can slow down the speeds of atoms from hundreds of meters per second to merely millimeters per second. This decrease in motion means that the atoms cool from room temperature to nearly absolute zero. Holding atoms at ultracold temperatures allows researchers to study their chemical reactions on the quantum mechanical level.

"Temperature is the main reason we don't experience many things that require quantum mechanics in our daily lives," said Wesley Campbell, a UCLA assistant professor of physics and astronomy, and co-author of the study. "At room temperature you don't really know the details of what's going on at the quantum scale. We can use these ultracold atoms to learn something about the chemistry that governs medicine and biology."

However, designing the powerful lasers necessary for this cooling—lasers that emit light of only one specific color and therefore energy—is an engineering challenge. The wavelength of the laser light has to be controlled to roughly one part in 100 million, which is like measuring the width of the United States to a precision of five centimeters. Furthermore, cooling biologically important atoms like hydrogen, oxygen, and carbon requires laser light that's in the very high-frequency ultraviolet part of the electromagnetic spectrum, and creating light this energetic is extremely difficult. In 1993, researchers in Italy successfully cooled hydrogen atoms using a laser, but the process was highly inefficient. "Nobody ever did it again," Campbell said.

Campbell and his team demonstrated a proof of concept to show that biologically important atoms could be reliably cooled using lasers. The researchers faced two challenges: creating laser light of a precise energy and showing that very high-frequency ultraviolet radiation could be reliably generated.

The researchers adopted a surprising approach that involved using an atypical kind of laser. Instead of a laser that emits a single color of light—what most people think of when they envision a laser—Campbell and his group tested a laser that emitted a range of colors, all shades of red. "It's a single laser, but it's lots of colors," said Xueping Long, a UCLA graduate student in Campbell's laboratory and a co-author of the paper.

The researchers were initially worried that all of the slightly different red wavelengths of light would be detrimental to their experiment. "If you have light on at the wrong color, it typically heats things and causes problems," said lead author Andrew Jayich, who was a UCLA postdoctoral researcher in Campbell's laboratory when this research was conducted and is now an assistant professor of physics at UC Santa Barbara.

However, when the UCLA scientists pointed their multicolored laser beam toward roughly 10 million atoms, they successfully demonstrated that pairs of photons emitted by the laser could be simultaneously absorbed by atoms. When absorbed in tandem, these pairs of photons mimicked light with precisely the energy necessary to cool the atoms. "Two photons play the role of one photon with twice the energy," Jayich said.

The researchers showed, for the first time, that pairs of photons could be used to reliably cool atoms. The final temperature of the atoms was 0.000057 degrees above absolute zero.

By combining red photons, the researchers demonstrated a method that can be used to create the energy of very high-frequency ultraviolet light, without the difficulties of actually generating such photons. "We've done something that sounds like it shouldn't work at all," Campbell said.

The scientists demonstrated their technique with rubidium, a heavy atom with 37 protons. "Rubidium is the easiest atom to work with; it's nature's gift to atomic physicists," Campbell said. But he and his team are looking forward to how their technique can be adapted for use with more common elements such as hydrogen, carbon, oxygen and nitrogen.

"These atoms are what you and I are made of, what the planet is made of, and what stars are made of," Campbell said. "We're interested in getting access to these atoms that atomic physicists have basically given up on." [13]

Physicists discover 'smoke rings' made of laser light

Most basic physics textbooks describe laser light in fairly simple terms: a beam travels directly from one point to another and, unless it strikes a mirror or other reflective surface, will continue traveling along an arrow-straight path, gradually expanding in size due to the wave nature of light. But these basic rules go out the window with high-intensity laser light.

Powerful laser beams, given the right conditions, will act as their own lenses and "self-focus" into a tighter, even more intense beam. University of Maryland physicists have discovered that these self-focused laser pulses also generate violent swirls of optical energy that strongly resemble smoke rings. In these donut-shaped light structures, known as "spatiotemporal optical vortices," the light energy flows through the inside of the ring and then loops back around the outside.

The vortices travel along with the laser pulse at the speed of light and control the energy flow around it. The newly discovered optical structures are described in the September 9, 2016 issue of the journal Physical Review X.

The researchers named the laser smoke rings "spatiotemporal optical vortices," or STOVs. The light structures are ubiquitous and easily created with any powerful laser, given the right conditions. The team strongly suspects that STOVs could explain decades' worth of anomalous results and unexplained effects in the field of high-intensity laser research.

"Lasers have been researched for decades, but it turns out that STOVs were under our noses the whole time," said Howard Milchberg, professor of physics and electrical and computer engineering at UMD and senior author of the research paper, who also has an appointment at the UMD Institute for Research in Electronics and Applied Physics (IREAP). "This is a robust, spontaneous feature that's always there. This phenomenon underlies so much that's been done in our field for the past 30-some years."

More conventional spatial optical vortices are well-known from prior research—chief among them "orbital angular momentum" (OAM) vortices, where light energy circulates around the beam propagation direction much like water rotates around a drain as it empties from a washbasin. Because these vortices can influence the shape of the central beam, they have proven useful for advanced applications such as high-resolution microscopy.

Spatiotemporal optical vortices, or STOVs (thin, gray ringlike objects), are newly described three-dimensional light structures that strongly resemble smoke rings. Unlike other laser vortices, STOVs are time dynamic, which means that they travel along with the central laser pulse. Compared to other laser vortices, STOVs could prove more broadly useful for engineering applications.

"Conventional optical vortices have been studied since the late 1990s as a way to improve telecommunications, microscopy and other applications. These vortices allow you to control what gets illuminated and what doesn't, by creating small structures in the light itself," said the paper's lead author Nihal Jhajj, a physics graduate student who conducted the research at IREAP.

"The smoke ring vortices we discovered may have even broader applications than previously known optical vortices, because they are time dynamic, meaning that they move along with the beam instead of remaining stationary," Jhajj added. "This means that the rings may be useful for manipulating particles moving near the speed of light."

Jhajj and Milchberg acknowledge that much more work needs to be done to understand STOVs, including their physical and theoretical implications. But they are particularly excited for new opportunities that will arise in basic laser research following their discovery of STOVs.

"All the evidence we've seen suggests that STOVs are universal," Jhajj said. "Now that we know what to look for, we think that looking at a high-intensity laser pulse propagating through a medium and not seeing STOVs would be a lot like looking at a river and not seeing eddies and currents."

Eventually, STOVs might have useful real-world applications, like their more conventional counterparts. For example, OAM vortices have been used in the design of more powerful stimulated emission depletion (STED) microscopes. STED microscopes are capable of much higher resolution than traditional confocal microscopes, in part due to the precise illumination offered by optical vortices.

With the potential to travel with the central beam at the speed of light, STOVs could have as-yet unforeseen advantages in technological applications, including the potential to expand the effective bandwidth of fiber-optic communication lines.

"A STOV is not just a spectator to the laser beam, like an angel's halo," explained Milchberg, noting the ability of STOVs to control the central beam's shape and energy flow. "It is more like an electrified angel's halo, with energy shooting back and forth between the halo and the angel's head. We're all very excited to see where this discovery will take us in the future." [12]

Electrons fingerprint the fastest laser pulses

Analyzing ultrafast chemical processes requires ultrafast lasers—light pulses lasting for mere attoseconds (10-18 second)—to act as a "stop-motion" strobe camera. Physicists at the University of Nebraska-Lincoln are analyzing how ultrafast laser pulses interact with matter. Their study of how two attosecond laser pulses would interact with a helium atom produced an electron momentum distribution that displays an unexpected two-armed vortex pattern, resembling a spiral galaxy.

Attosecond-duration laser pulses provide a new tool with the potential to provide key insights on ultrafast chemical processes and ultimately to control processes that underlie energy-relevant technologies, such as solar energy conversion and catalysis. But before this new tool can meet its full potential, the pulses themselves and their fundamental interactions with matter must be understood. In this case, the researchers reveal vortex patterns produced by attosecond laser pulses can serve as an excellent diagnostic tool for characterizing the electron-manipulating laser pulses. For example, the pattern can be used to determine the intensity of the pulses and the time delay between them.

When interrogating matter with a laser pulse, the duration of the pulse plays a major role in determining the information that can be acquired. In general, the process that is being studied must occur on the same time scale as the laser pulse. For this reason, chemical dynamics processes, which often occur on the femtosecond-to-attosecond time scale, are difficult to study. Recent technological developments are beginning to make attosecond laser pulses a reality, but a great deal of mystery still surrounds the processes that these laser pulses could unveil. Scientists will often use computer simulations, based on quantum mechanical principles, to predict the ultrafast laser interactions they seek to replicate experimentally.

Physicists at the University of Nebraska-Lincoln have taken this approach and simulated the interaction of a helium atom with two time-delayed attosecond laser pulses of opposite circular polarization. The resulting electron momentum distribution displays an unexpected two-armed vortex pattern. The team's first pulse of circularly polarized light rotated in one direction, with the second rotating the opposite way. These orientations dictate whether the resulting spiral pattern appears to swirl left or right. The time delay between the pulses determines the number of windings of the two spiral arms, whereas the duration of the pulses corresponds to the width of the arms. This pattern is significant because it has been observed previously in the interaction of laser beams, but never with electrons. The similarity of the vortex pattern highlights the wave-particle duality of the electron, which describes how it behaves both as a particle and as a wave.

Additionally, the discovery of the vortex pattern has many potential practical applications. Due to the extreme sensitivity of the vortex pattern to the time delay between the two pulses, analyzing the pattern could help characterize the time delay and intensity of attosecond laser pulses. Similarly, the vortex pattern could be used as a "stopwatch" to determine the duration of ultrafast processes.

Also, the ability to produce a specific momentum pattern with this interaction demonstrates a new way to control electron motion with laser pulses. [11]

Superfast light pulses able to measure response time of electrons to light

A team of researchers with members from Germany, the U.S. and Russia has found a way to measure the time it takes for an electron in an atom to respond to a pulse of light. In their paper published in the journal Nature, the team describes their use of a light field synthesizer to create pulses of light so fast that they were able to reveal the time it took for electrons in an atom to respond when struck. Kyung Taec Kim with the Gwangju Institute of Science offers a News & Views piece on the work done by the team in the same journal issue, outlining their work and noting one issue that still needs to be addressed with such work.

As scientists have begun preparing for the day when photons will replace electrons in high speed computers, work is being done to better understand the link between the two. One important aspect of this is learning what happens when photons strike electrons that remain in their atom (rather than being knocked out of them), specifically, how long does it take them to respond.

To find this answer, the researchers used what has come to be known as a light-field synthesizer—it is a device that is able to produce pulses of light that are just half of a single wavelength long—something many had thought was impossible not too long ago. The pulses are of such short duration that they only last for the time it takes to travel that half wavelength, which in this case, was approximately 380 attoseconds.

The light-field synthesizer works by combining several pulses of light brought together but slightly out of phase, allowing for canceling and ultimately, a single very short pulse. In their experiments, the researchers fired their super-short pulses at krypton atoms held inside of a vacuum. In so doing, they found that it took the electrons 115 attoseconds to respond—the first such measurement of the response time of an electron to a visible light pulse.

The team plans to continue their work by looking at how electrons behave in other materials, and as Kim notes, finding a way to characterize both the amplitude and phase of radiation from atoms driven by a light field. [10]

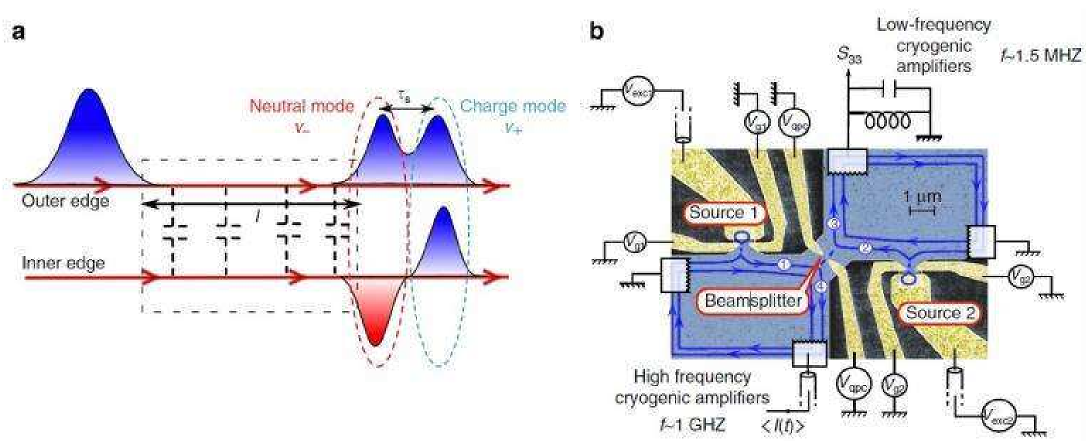
When an electron splits in two

Now in a new paper published in Nature Communications, a team of physicists led by Gwendal Fève at the Ecole Normale Supérieure in Paris and the Laboratory for Photonics and Nanostructures in Marcoussis have applied an experiment typically used to study photons to investigate the underlying mechanisms of electron fractionalization. The method allows the researchers to observe single-electron fractionalization on the picosecond scale.

"We have been able to visualize the splitting of an electronic wavepacket into two fractionalized packets carrying half of the original electron charge," Fève told Phys.org. "Electron fractionalization has been studied in previous works, mainly during roughly the last five years. Our work is the first to combine single-electron resolution—which allows us to address the fractionalization process at the elementary scale—with time resolution to directly visualize the fractionalization process."

The technique that the researchers used is called the Hong-Ou-Mandel experiment, which can be used to measure the degree of resemblance between two photons, or in this case electron charge pulses, in an interferometer. This experiment also requires a single-electron emitter, which some of the same researchers, along with many others, have recently been developing.

The researchers first analyzed the propagation of a single electron in the interferometer's outer one-dimensional wire, and then when that electron fractionalized, they could observe the interaction between its two charge pulses in the inner one-dimensional wire. As the researchers explain, when the original electron travels along the outer wire, Coulomb interactions (interactions between charged particles) between excitations in the outer and inner wires produce two types of excitation pairs: two pulses of the same sign (carrying a net charge) and two pulses of opposite signs (which together are neutral). The two different excitation pairs travel at different velocities, again due to Coulomb interactions, which causes the original electron to split into two distinct charge pulses.



(a) An electron on the outer channel fractionalizes into two pulses. (b) A modified scanning electron microscope picture of the sample. Credit: Freulon, et al. ©2015 Nature

The experiment reveals that, when a single electron fractionalizes into two pulses, the final state cannot be described as a single-particle state, but rather as a collective state composed of several excitations. For this reason, the fractionalization process destroys the original electron particle. Electron destruction can be measured by the decoherence of the electron's wave packet.

Gaining a better understanding of electron fractionalization could have a variety of implications for research in condensed matter physics, such as controlling single-electron currents in one-dimensional wires.

"There has been, during the past years, strong efforts to control and manipulate the propagation of electrons in electronic conductors," Fève said. "It bears many analogies with the manipulations of the quantum states of photons performed in optics. For such control, one-dimensional conductors are useful, as they offer the possibility to guide the electrons along a one-dimensional trajectory. However, Coulomb interactions between electrons are also very strong in one-dimensional wires, so strong that electrons are destroyed: they fractionalize. Understanding fractionalization is understanding the destruction mechanism of an elementary electron in a one-dimensional wire. Such understanding is very important if one wants to control electronic currents at the elementary scale of a single electron."

In the future, the researchers plan to perform further experiments with the Hong-Ou-Mandel interferometer in order to better understand why fractionalization leads to electron destruction, and possibly how to suppress fractionalization.

"The Hong-Ou-Mandel interferometer can be used to picture the temporal extension (or shape) of the electronic wavepackets, which is what we used to visualize the fractionalization process," Fève said. "It can also be used to capture the phase relationship (or phase coherence) between two components of the electronic wavepacket.

"This combined information fully defines the single-electron state, offering the possibility to visualize the wavefunction of single electrons propagating in a one-dimensional conductor. This would first provide a complete understanding of the fractionalization mechanism and in particular how it leads to the decoherence of single-electron states. It would also offer the possibility to test if single electrons can be protected from this decoherence induced by Coulomb interaction. Can we suppress (or reduce) the fractionalization process by reducing the strength of the Coulomb interaction? We would then be able to engineer and visualize pure single-electron states, preserved from Coulomb interaction.

"The next natural step is then to address few-particle states and electron entanglement in quantum conductors. Again, the question of the destruction of such states by Coulomb interaction effects will be a crucial one." [9]

The Electromagnetic Interaction

This paper explains the magnetic effect of the electric current from the observed effects of the accelerating electrons, causing naturally the experienced changes of the electric field potential along the electric wire. The accelerating electrons explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the wave particle duality and the electron's spin also, building the bridge between the Classical and Quantum Theories. [2]

Asymmetry in the interference occurrences of oscillators

The asymmetrical configurations are stable objects of the real physical world, because they cannot annihilate. One of the most obvious asymmetry is the proton – electron mass rate M_p = 1840 M_e while they have equal charge. We explain this fact by the strong interaction of the proton, but how remember it his strong interaction ability for example in the H – atom where are only electromagnetic interactions among proton and electron.

This gives us the idea to origin the mass of proton from the electromagnetic interactions by the way interference occurrences of oscillators. The uncertainty relation of Heisenberg makes sure that the particles are oscillating.

The resultant intensity due to n equally spaced oscillators, all of equal amplitude but different from one another in phase, either because they are driven differently in phase or because we are looking at them an angle such that there is a difference in time delay:

(1) $I = I_0 \sin^2 n\,\phi/2 \,/\, \sin^2 \phi/2$

If ϕ is infinitesimal so that $\sin\phi = \phi$, than

(2) $I = n^2 I_0$

This gives us the idea of

(3) $M_p = n^2 M_e$

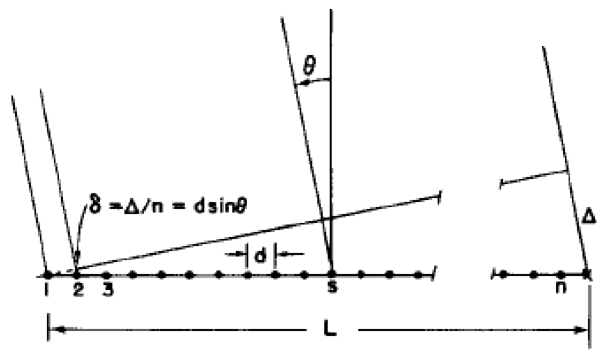


Fig. 30–3. A linear array of *n* equal oscillators, driven with phases $\alpha_s = s\alpha$.

Figure 1.) A linear array of n equal oscillators

There is an important feature about formula (1) which is that if the angle ϕ is increased by the multiple of 2π, it makes no difference to the formula.

So

(4) $d \sin \theta = m \lambda$

and we get m-order beam if λ less than d. [6]

If d less than λ we get only zero-order one centered at $\theta = 0$. Of course, there is also a beam in the opposite direction. The right chooses of d and λ we can ensure the conservation of charge.

For example

(5) $2(m+1) = n$

Where 2(m+1) = N_p number of protons and n = N_e number of electrons.

In this way we can see the H_2 molecules so that 2n electrons of n radiate to 4(m+1) protons, because $d_e > \lambda_e$ for electrons, while the two protons of one H_2 molecule radiate to two electrons of them, because of $d_e < \lambda_e$ for this two protons.

To support this idea we can turn to the Planck distribution law, that is equal with the Bose – Einstein statistics.

Spontaneously broken symmetry in the Planck distribution law

The Planck distribution law is temperature dependent and it should be true locally and globally. I think that Einstein's energy-matter equivalence means some kind of existence of electromagnetic oscillations enabled by the temperature, creating the different matter formulas, atoms molecules, crystals, dark matter and energy.

Max Planck found for the black body radiation

As a function of wavelength (λ), Planck's law is written as:

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1}.$$

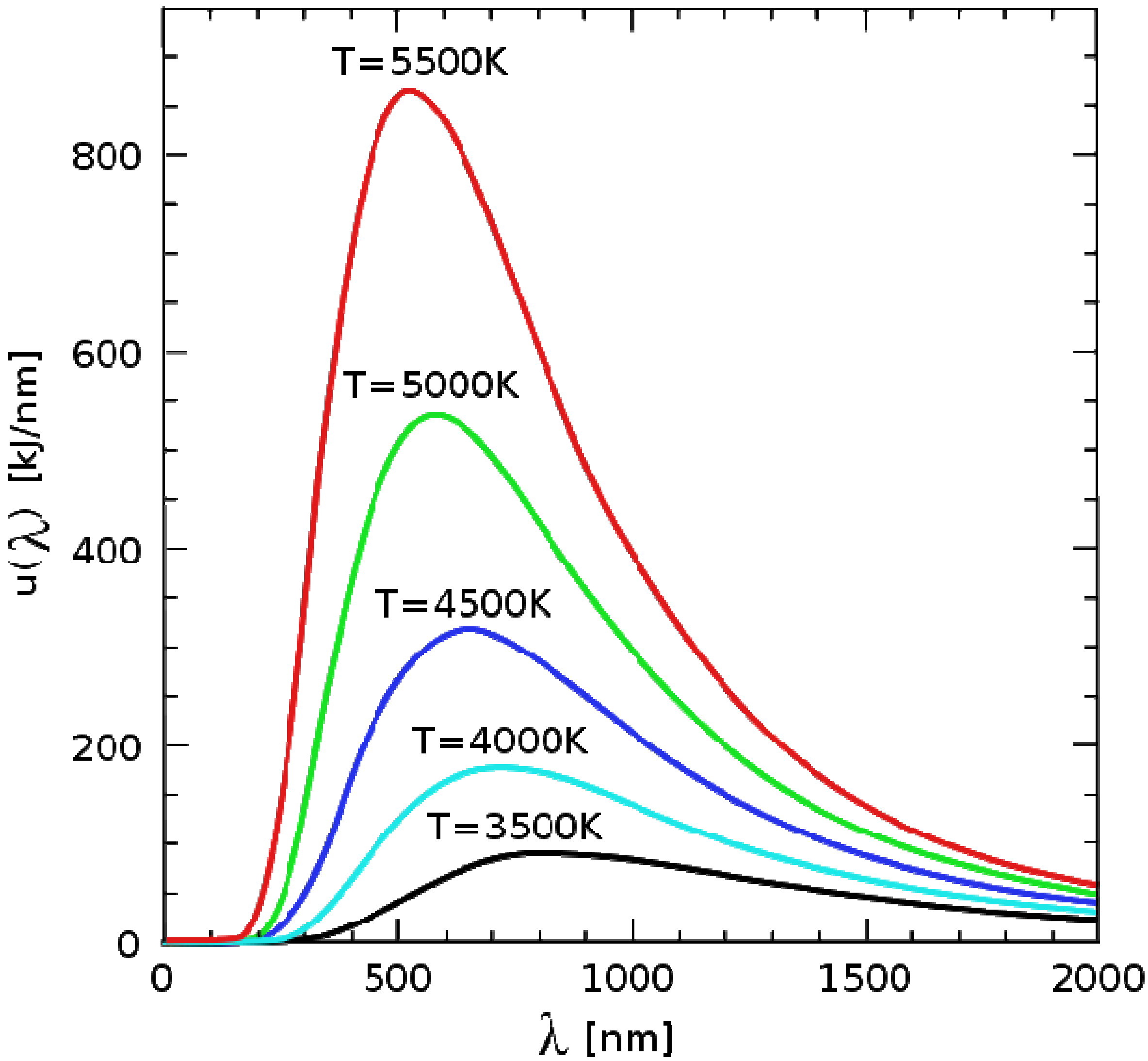


Figure 2. The distribution law for different T temperatures

We see there are two different λ_1 and λ_2 for each T and intensity, so we can find between them a d so that $\lambda_1 < d < \lambda_2$.

We have many possibilities for such asymmetrical reflections, so we have many stable oscillator configurations for any T temperature with equal exchange of intensity by radiation. All of these configurations can exist together. At the λ_{max} is the annihilation point where the configurations are symmetrical. The λ_{max} is changing by the Wien's displacement law in many textbooks.

(7) $$\lambda_{\max} = \frac{b}{T}$$

where λ_{max} is the peak wavelength, T is the absolute temperature of the black body, and b is a constant of proportionality called *Wien's displacement constant*, equal to $2.8977685(51)\times10^{-3}$ m·K (2002 CODATA recommended value).

By the changing of T the asymmetrical configurations are changing too.

The structure of the proton

We must move to the higher T temperature if we want look into the nucleus or nucleon arrive to $d<10^{-13}$ cm. If an electron with $\lambda_e < d$ move across the proton then by (5) 2 (m+1) = n with m = 0 we get n = 2 so we need two particles with negative and two particles with positive charges. If the proton can fraction to three parts, two with positive and one with negative charges, then the reflection of oscillators are right. Because this very strange reflection where one part of the proton with the electron together on the same side of the reflection, the all parts of the proton must be quasi lepton so $d > \lambda_q$. One way dividing the proton to three parts is, dividing his oscillation by the three direction of the space. We can order 1/3 e charge to each coordinates and 2/3 e charge to one plane oscillation, because the charge is scalar. In this way the proton has two +2/3 e plane oscillation and one linear oscillation with -1/3 e charge. The colors of quarks are coming from the three directions of coordinates and the proton is colorless. The flavors of quarks are the possible oscillations differently by energy and if they are plane or linear oscillations. We know there is no possible reflecting two oscillations to each other which are completely orthogonal, so the quarks never can be free, however there is an asymptotic freedom while their energy are increasing to turn them to the orthogonally. If they will be completely orthogonal then they lose this reflection and take new partners from the vacuum. Keeping the symmetry of the vacuum the new oscillations are keeping all the conservation laws, like charge, number of baryons and leptons. The all features of gluons are coming from this model. The mathematics of reflecting oscillators show Fermi statistics.

Important to mention that in the Deuteron there are 3 quarks of +2/3 and -1/3 charge, that is three u and d quarks making the complete symmetry and because this its high stability.

The Pauli Exclusion Principle says that the diffraction points are exclusive!

The Strong Interaction

Confinement and Asymptotic Freedom

For any theory to provide a successful description of strong interactions it should simultaneously exhibit the phenomena of confinement at large distances and asymptotic freedom at short distances. Lattice calculations support the hypothesis that for non-abelian gauge theories the two domains are analytically connected, and confinement and asymptotic freedom coexist.
Similarly, one way to show that QCD is the correct theory of strong interactions is that the coupling extracted at various scales (using experimental data or lattice simulations) is unique in the sense that its variation with scale is given by the renormalization group. [4]
Lattice QCD gives the same results as the diffraction theory of the electromagnetic oscillators, which is the explanation of the strong force and the quark confinement. [1]

The weak interaction

The weak interaction transforms an electric charge in the diffraction pattern from one side to the other side, causing an electric dipole momentum change, which violates the CP and time reversal symmetry.

Another important issue of the quark model is when one quark changes its flavor such that a linear oscillation transforms into plane oscillation or vice versa, changing the charge value with 1 or -1. This kind of change in the oscillation mode requires not only parity change, but also charge and time changes (CPT symmetry) resulting a right handed anti-neutrino or a left handed neutrino.

The right handed anti-neutrino and the left handed neutrino exist only because changing back the quark flavor could happen only in reverse, because they are different geometrical constructions, the u is 2 dimensional and positively charged and the d is 1 dimensional and negatively charged. It needs also a time reversal, because anti particle (anti neutrino) is involved.

The neutrino is a 1/2spin creator particle to make equal the spins of the weak interaction, for example neutron decay to 2 fermions, every particle is fermions with ½ spin. The weak interaction changes the entropy since more or less particles will give more or less freedom of movement. The entropy change is a result of temperature change and breaks the equality of oscillator diffraction intensity of the Maxwell–Boltzmann statistics. This way it changes the time coordinate measure and makes possible a different time dilation as of the special relativity.

The limit of the velocity of particles as the speed of light appropriate only for electrical charged particles, since the accelerated charges are self maintaining locally the accelerating electric force. The neutrinos are CP symmetry breaking particles compensated by time in the CPT symmetry, that is the time coordinate not works as in the electromagnetic interactions, consequently the speed of neutrinos is not limited by the speed of light.

The weak interaction T-asymmetry is in conjunction with the T-asymmetry of the second law of thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes the weak interaction, for example the Hydrogen fusion.

Probably because it is a spin creating movement changing linear oscillation to 2 dimensional oscillation by changing d to u quark and creating anti neutrino going back in time relative to the proton and electron created from the neutron, it seems that the anti neutrino fastest then the velocity of the photons created also in this weak interaction?

A quark flavor changing shows that it is a reflection changes movement and the CP- and T- symmetry breaking. This flavor changing oscillation could prove that it could be also on higher level such as atoms, molecules, probably big biological significant molecules and responsible on the aging of the life.

Important to mention that the weak interaction is always contains particles and antiparticles, where the neutrinos (antineutrinos) present the opposite side. It means by Feynman’s interpretation that these particles present the backward time and probably because this they seem to move faster than the speed of light in the reference frame of the other side.

Finally since the weak interaction is an electric dipole change with ½ spin creating; it is limited by the velocity of the electromagnetic wave, so the neutrino's velocity cannot exceed the velocity of light.

The General Weak Interaction

The Weak Interactions T-asymmetry is in conjunction with the T-asymmetry of the Second Law of

Thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes for example the Hydrogen fusion. The arrow of time by the Second Law of Thermodynamics shows the increasing entropy and decreasing information by the Weak Interaction, changing the temperature dependent diffraction patterns. A good example of this is the neutron decay, creating more particles with less known information about them.

The neutrino oscillation of the Weak Interaction shows that it is a general electric dipole change and it is possible to any other temperature dependent entropy and information changing diffraction pattern of atoms, molecules and even complicated biological living structures.

We can generalize the weak interaction on all of the decaying matter constructions, even on the biological too. This gives the limited lifetime for the biological constructions also by the arrow of time. There should be a new research space of the Quantum Information Science the 'general neutrino oscillation' for the greater then subatomic matter structures as an electric dipole change.

There is also connection between statistical physics and evolutionary biology, since the arrow of time is working in the biological evolution also.

The Fluctuation Theorem says that there is a probability that entropy will flow in a direction opposite to that dictated by the Second Law of Thermodynamics. In this case the Information is growing that is the matter formulas are emerging from the chaos. So the Weak Interaction has two directions, samples for one direction is the Neutron decay, and Hydrogen fusion is the opposite direction. [5]

Fermions and Bosons

The fermions are the diffraction patterns of the bosons such a way that they are both sides of the same thing.

The Higgs boson or Higgs particle is a proposed elementary particle in the Standard Model of particle physics. The Higgs boson's existence would have profound importance in particle physics because it would prove the existence of the hypothetical Higgs field - the simplest of several proposed explanations for the origin of the symmetry-breaking mechanism by which elementary particles gain mass. [3]

The fermions' spin

The moving charges are accelerating, since only this way can self maintain the electric field causing their acceleration. The electric charge is not point like! This constant acceleration possible if there is a rotating movement changing the direction of the velocity. This way it can accelerate forever without increasing the absolute value of the velocity in the dimension of the time and not reaching the velocity of the light.

The Heisenberg uncertainty relation says that the minimum uncertainty is the value of the spin: 1/2 h = d x d p or 1/2 h = d t d E, that is the value of the basic energy status.

What are the consequences of this in the weak interaction and how possible that the neutrinos' velocity greater than the speed of light?

The neutrino is the one and only particle doesn't participate in the electromagnetic interactions so we cannot expect that the velocity of the electromagnetic wave will give it any kind of limit.

The neutrino is a 1/2spin creator particle to make equal the spins of the weak interaction, for example neutron decay to 2 fermions, every particle is fermions with ½ spin. The weak interaction changes the entropy since more or less particles will give more or less freedom of movement. The entropy change is a result of temperature change and breaks the equality of oscillator diffraction intensity of the Maxwell–Boltzmann statistics. This way it changes the time coordinate measure and makes possible a different time dilation as of the special relativity.

The source of the Maxwell equations

The electrons are accelerating also in a static electric current because of the electric force, caused by the potential difference. The magnetic field is the result of this acceleration, as you can see in [2].

The mysterious property of the matter that the electric potential difference is self maintained by the accelerating electrons in the electric current gives a clear explanation to the basic sentence of the relativity that is the velocity of the light is the maximum velocity of the matter. If the charge could move faster than the electromagnetic field than this self maintaining electromagnetic property of the electric current would be failed.

Also an interesting question, how the changing magnetic field creates a negative electric field?
The answer also the accelerating electrons will give. When the magnetic field is increasing in time by increasing the electric current, then the acceleration of the electrons will increase, decreasing the charge density and creating a negative electric force. Decreasing the magnetic field by decreasing the electric current will decrease the acceleration of the electrons in the electric current and increases the charge density, creating an electric force also working against the change.
In this way we have explanation to all interactions between the electric and magnetic forces described in the Maxwell equations.
The second mystery of the matter is the mass. We have seen that the acceleration change of the electrons in the flowing current causing a negative electrostatic force. This is the cause of the relativistic effect - built-in in the Maxwell equations - that is the mass of the electron growing with its acceleration and its velocity never can reach the velocity of light, because of this growing negative electrostatic force. The velocity of light is depending only on 2 parameters: the magnetic permeability and the electric permittivity.
There is a possibility of the polarization effect created by electromagnetic forces creates the negative and positive charges. In case of equal mass as in the electron-positron pair it is simply, but

on higher energies can be asymmetric as the electron-proton pair of neutron decay by week interaction and can be understood by the Feynman graphs.
Anyway the mass can be electromagnetic energy exceptionally and since the inertial and gravitational mass are equals, the gravitational force is electromagnetic force and since only the magnetic force is attractive between the same charges, is very important for understanding the gravitational force.

The Uncertainty Relations of Heisenberg gives the answer, since only this way can be sure that the particles are oscillating in some way by the electromagnetic field with constant energies in the atom indefinitely. Also not by chance that the uncertainty measure is equal to the fermions spin, which is one of the most important feature of the particles. There are no singularities, because the moving electron in the atom accelerating in the electric field of the proton, causing a charge distribution on delta x position difference and with a delta p momentum difference such a way that they product is about the half Planck reduced constant. For the proton this delta x much less in the nucleon, than in the orbit of the electron in the atom, the delta p is much higher because of the greatest proton mass.

The Special Relativity

The mysterious property of the matter that the electric potential difference is self maintained by the accelerating electrons in the electric current gives a clear explanation to the basic sentence of the relativity that is the velocity of the light is the maximum velocity of the matter. If the charge could move faster than the electromagnetic field than this self maintaining electromagnetic property of the electric current would be failed. [8]

The Heisenberg Uncertainty Principle

Moving faster needs stronger acceleration reducing the dx and raising the dp. It means also mass increasing since the negative effect of the magnetic induction, also a relativistic effect!

The Uncertainty Principle also explains the proton – electron mass rate since the dx is much less requiring bigger dp in the case of the proton, which is partly the result of a bigger mass m_p because of the higher electromagnetic induction of the bigger frequency (impulse).

The Gravitational force

The changing magnetic field of the changing current causes electromagnetic mass change by the negative electric field caused by the changing acceleration of the electric charge.

The gravitational attractive force is basically a magnetic force.

The same electric charges can attract one another by the magnetic force if they are moving parallel in the same direction. Since the electrically neutral matter is composed of negative and positive charges they need 2 photons to mediate this attractive force, one per charges. The Bing Bang caused parallel moving of the matter gives this magnetic force, experienced as gravitational force.

Since graviton is a tensor field, it has spin = 2, could be 2 photons with spin = 1 together.

You can think about photons as virtual electron – positron pairs, obtaining the necessary virtual mass for gravity.

The mass as seen before a result of the diffraction, for example the proton – electron mass rate M_p = 1840 M_e. In order to move one of these diffraction maximum (electron or proton) we need to intervene into the diffraction pattern with a force appropriate to the intensity of this diffraction maximum, means its intensity or mass. [1]

The Big Bang caused acceleration created radial currents of the matter, and since the matter is composed of negative and positive charges, these currents are creating magnetic field and attracting forces between the parallel moving electric currents. This is the gravitational force experienced by the matter, and also the mass is result of the electromagnetic forces between the charged particles. The positive and negative charged currents attracts each other or by the magnetic forces or by the much stronger electrostatic forces!?

The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.
There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

The Graviton

In physics, the graviton is a hypothetical elementary particle that mediates the force of gravitation in the framework of quantum field theory. If it exists, the graviton is expected to be massless (because the gravitational force appears to have unlimited range) and must be a spin-2 boson. The spin follows from the fact that the source of gravitation is the stress-energy tensor, a second-rank tensor (compared to electromagnetism's spin-1 photon, the source of which is the four-current, a first-rank tensor). Additionally, it can be shown that any massless spin-2 field would give rise to a force indistinguishable from gravitation, because a massless spin-2 field must couple to (interact with) the stress-energy tensor in the same way that the gravitational field does. This result suggests that, if a massless spin-2 particle is discovered, it must be the graviton, so that the only experimental verification needed for the graviton may simply be the discovery of a massless spin-2 particle. [3]

What is the Spin?

So we know already that the new particle has spin zero or spin two and we could tell which one if we could detect the polarizations of the photons produced. Unfortunately this is difficult and neither ATLAS nor CMS are able to measure polarizations. The only direct and sure way to confirm that the particle is indeed a scalar is to plot the angular distribution of the photons in the rest frame of the centre of mass. A spin zero particles like the Higgs carries no directional information away from the original collision so the distribution will be even in all directions. This test will be possible when a much larger number of events have been observed. In the mean time we can settle for less certain indirect indicators.

The Casimir effect

The Casimir effect is related to the Zero-point energy, which is fundamentally related to the Heisenberg uncertainty relation. The Heisenberg uncertainty relation says that the minimum uncertainty is the value of the spin: 1/2 h = dx dp or 1/2 h = dt dE, that is the value of the basic energy status.

The moving charges are accelerating, since only this way can self maintain the electric field causing their acceleration. The electric charge is not point like! This constant acceleration possible if there is a rotating movement changing the direction of the velocity. This way it can accelerate forever without increasing the absolute value of the velocity in the dimension of the time and not reaching the velocity of the light. In the atomic scale the Heisenberg uncertainty relation gives the same result, since the moving electron in the atom accelerating in the electric field of the proton, causing a charge distribution on delta x position difference and with a delta p momentum difference such a way that they product is about the half Planck reduced constant. For the proton this delta x much less in the nucleon, than in the orbit of the electron in the atom, the delta p is much higher because of the greater proton mass. This means that the electron is not a point like particle, but has a real charge distribution.

Electric charge and electromagnetic waves are two sides of the same thing; the electric charge is the diffraction center of the electromagnetic waves, quantified by the Planck constant h.

The Fine structure constant

The Planck constant was first described as the proportionality constant between the energy (*E*) of a photon and the frequency (*ν*) of its associated electromagnetic wave. This relation between the energy and frequency is called the **Planck relation** or the **Planck–Einstein equation**:

$$E = h\nu\,.$$

Since the frequency ν, wavelength *λ*, and speed of light *c* are related by *λν* = *c*, the Planck relation can also be expressed as

$$E = \frac{hc}{\lambda}.$$

Since this is the source of Planck constant, the e electric charge countable from the Fine structure constant. This also related to the Heisenberg uncertainty relation, saying that the mass of the proton should be bigger than the electron mass because of the difference between their wavelengths.

The expression of the fine-structure constant becomes the abbreviated

$$\alpha = \frac{e^2}{\hbar c}$$

This is a dimensionless constant expression, 1/137 commonly appearing in physics literature.

This means that the electric charge is a result of the electromagnetic waves diffractions, consequently the proton – electron mass rate is the result of the equal intensity of the corresponding electromagnetic frequencies in the Planck distribution law, described in my diffraction theory.

Path integral formulation of Quantum Mechanics

The path integral formulation of quantum mechanics is a description of quantum theory which generalizes the action principle of classical mechanics. It replaces the classical notion of a single, unique trajectory for a system with a sum, or functional integral, over an infinity of possible trajectories to compute a quantum amplitude. [7]

It shows that the particles are diffraction patterns of the electromagnetic waves.

Conclusions

"The next natural step is then to address few-particle states and electron entanglement in quantum conductors. Again, the question of the destruction of such states by Coulomb interaction effects will be a crucial one." [9]

The magnetic induction creates a negative electric field, causing an electromagnetic inertia responsible for the relativistic mass change; it is the mysterious Higgs Field giving mass to the particles. The Planck Distribution Law of the electromagnetic oscillators explains the electron/proton mass rate by the diffraction patterns. The accelerating charges explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the wave particle duality and the electron's spin also, building the bridge between the Classical and Relativistic Quantum Theories. The self maintained electric potential of the accelerating charges equivalent with the General Relativity space-time curvature, and since it is true on the quantum level also, gives the base of the Quantum Gravity. The electric currents causing self maintaining electric potential is the source of the special and general relativistic effects. The Higgs Field is the result of the electromagnetic induction. The Graviton is two photons together.

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