Frequency Combs

EPFL scientists have found a way to miniaturize frequency combs, realizing a new step toward miniaturization of such tools. Their device can measure light oscillations with a precision of 12 digits. [20]

Technion researchers have demonstrated, for the first time, that laser emissions can be created through the interaction of light and water waves. This "water-wave laser" could someday be used in tiny sensors that combine light waves, sound and water waves, or as a feature on microfluidic "lab-on-a-chip" devices used to study cell biology and to test new drug therapies. [18]

Researchers led by EPFL have built ultra-high quality optical cavities for the elusive mid-infrared spectral region, paving the way for new chemical and biological sensors, as well as promising technologies. [17]

The research team led by Professor Hele Savin has developed a new light detector that can capture more than 96 percent of the photons covering visible, ultraviolet and infrared wavelengths. [16]

A promising route to smaller, powerful cameras built into smartphones and other devices is to design optical elements that manipulate light by diffraction-the bending of light around obstacles or through small gaps-instead of refraction. [15]

Converting a single photon from one color, or frequency, to another is an essential tool in quantum communication, which harnesses the subtle correlations between the subatomic properties of photons (particles of light) to securely store and transmit information. Scientists at the National Institute of Standards and Technology (NIST) have now developed a miniaturized version of a frequency converter, using technology similar to that used to make computer chips. [14]

Harnessing the power of the sun and creating light-harvesting or light-sensing devices requires a material that both absorbs light efficiently and converts the energy to highly mobile electrical current. Finding the ideal mix of properties in a single material is a challenge, so scientists have been experimenting with ways to combine different materials to create "hybrids" with enhanced features. [13]

Condensed-matter physicists often turn to particle-like entities called quasiparticles—such as excitons, plasmons, magnons—to explain complex phenomena. Now Gil Refael from the California Institute of Technology in Pasadena and colleagues report the theoretical concept of the topological *polarition, or "topolariton": a hybrid half-light, half-matter quasiparticle that has special topological properties and might be used in devices to transport light in one direction. [12]*

Solitons are localized wave disturbances that propagate without changing shape, a result of a nonlinear interaction that compensates for wave packet dispersion. Individual solitons may collide, but a defining feature is that they pass through one another and emerge from the collision unaltered in shape, amplitude, or velocity, but with a new trajectory reflecting a discontinuous jump.

Working with colleagues at the Harvard-MIT Center for Ultracold Atoms, a group led by Harvard Professor of Physics Mikhail Lukin and MIT Professor of Physics Vladan Vuletic have managed to coax photons into binding together to form molecules – a state of matter that, until recently, had been purely theoretical. The work is described in a September 25 paper in Nature.

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

Frequency combs—on-chip integration on track

EPFL scientists have found a way to miniaturize frequency combs, realizing a new step toward miniaturization of such tools. Their device can measure light oscillations with a precision of 12 digits.

A compact, precision tool for counting and tracking laser frequencies may improve atomic clocks and optical data transmission devices. However, light waves oscillate hundreds of trillions of times per second, a frequency that is impossible to measure directly. Large pulsed laser sources are typically used to produce "frequency combs" that can link the optical domain to the radio frequencies and make counting the oscillations of light possible. EPFL scientists have found a way to miniaturize frequency combs, realizing a new step toward miniaturization of such tools. Their device was capable of measuring light oscillations with a precision of 12 digits. The work is published in the journal Light: Science and Applications.

The lab of Tobias J. Kippenberg at EPFL, in a project led by Victor Brasch and Erwan Lucas, created what is called a "self-referenced optical frequency comb". This is essentially a series of densely-spaced spectral lines whose spacing is identical and known. Because they are so well defined, optical frequency combs can be used as a "ruler" for measuring the frequency – or color – of any laser beam. By comparing an unknown color to this ruler, it is possible to calculate its frequency. However, this implies a critical step called "self-referencing", a method that exactly determines the position of each individual tick of the frequency ruler, but demands a very long ruler – a broad spectral range, as scientists say – which is challenging to obtain.

Although optical frequency combs earned their inventors the Nobel prize in Physics in 2005, they still required bulky optical setups. Prof. Kippenberg's lab showed in 2007 that optical frequency combs could be created using tiny devices called "optical microresonators": microscopic ring-shaped structures made from very fine silicon nitride measuring a few millimeters to a few tens of microns in diameter. These structures can trap a continuous laser light and convert it into ultra-short pulses – solitons – thanks to the special nonlinear properties of the device. The solitons travel around the microresonator 200 billion times per second and the pulsed output from the microresonator creates the optical frequency comb.

Last year, the group solved an outstanding challenge, demonstrating that a careful control of the microresonator parameters, enabled to generate a very broad frequency spectrum directly on-chip. At this point, the frequencies generated extend over two thirds of an octave compared with the frequency of the incoming laser (an octave refers to either double or half the frequency). When combined with a laser transfer system, based on non-linear crystals, the team's approach enabled self-referencing, while eliminating the need for bulky, external systems traditionally used for frequency broadening.

With this, the researchers could prove that their optical frequency comb can be used for the most precise measurement applications: they measured the frequency of a laser using their technique as well as a traditional frequency comb system and showed that the two results agreed over 12 digits.

The technology is amenable to integration with both photonic elements and silicon microchips. Establishing devices that provide a RF to optical link on a chip may catalyze a wide variety of applications such as integrated, atomic clocks and on-chip, and could contribute to making optical frequency metrology ubiquitous. [20]

Laser-driving of semimetals allows creating novel quasiparticle states

Studying properties of fundamental particles in condensed matter systems is a promising approach to quantum field theory. Quasiparticles offer the opportunity to observe particle properties that have no realization in elementary particles. In the present study, an international research team led by Angel Rubio from the Max Planck Institute for the Structure and Dynamics of Matter at CFEL in Hamburg and the University of the Basque Country in Donostia-San Sebastián predicted how laser light can be used to create Weyl fermion states in 3-D Dirac materials and to switch between Weyl semimetal, Dirac semimetal and topological insulator states on ultrafast timescales. Besides its relevance for fundamental quantum physics, the results might lead to applications in ultrafast switching of material properties. The findings are published online in the journal Nature Communications today.

In the standard model of particle physics, the fundamental particles that make up all matter around us – electrons and quarks – are so-called fermions, named after the famous Italian physicist Enrico Fermi. Quantum theory predicts that elementary fermions could exist as three different kinds: Dirac, Weyl, and Majorana fermions, named after Paul Dirac, Hermann Weyl, and Ettore Majorana. However, despite being predicted almost a hundred years ago, of these three kinds of particles only Dirac fermions have been observed as elementary particles in nature so far. With the discovery of graphene in 2004, however, it was realized that the behaviour of relativistic free particles could be observed in the electronic properties of materials. This sparked the search for materials where these fundamental particles could be observed and only last year the first materials hosting Weyl fermions were discovered. While any known material only hosts one kind of these fermions in its equilibrium state, in the present work it is demonstrated how one can transform the fermion nature within specific materials by using tailored light pulses.

First observation of Dirac fermions in graphene

The observation of Dirac fermions in the properties of graphene originates from a complex interaction of the large number of electrons and ions that make up the material. Although each individual electron interacts with its surrounding ions and electrons via electrostatic forces, the particular pattern of carbon ions in graphene's honeycomb layer structure causes the electrons to behave collectively like massless, free fermions – Dirac fermions. These particles cooperatively forming new particles with different properties are called quasiparticles. The hunt for other materials hosting quasiparticles behaving like fundamental particles has thus focused on the crystal structure of materials so far.

Creating laser-driven topological states

It has now been found, however, that by irradiating a material with a laser, it is also possible to combine a quasiparticle with the photons of the laser field to form a new quasiparticle that, again, can behave fundamentally differently. In particular, the coupling to photons can affect the topology of quasiparticles. Topology is a property of the particles that leads to peculiar properties, for example metallic chiral edge states that form a collisionless one-way quantum highway along the edge of a topological insulator. This chirality, or handedness, is topological in the sense that right-handed and left-handed chiralities are discrete states that cannot be continuously deformed into each other. The 2016 Nobel Prize in Physics was just awarded to Michael Kosterlitz, Duncan Haldane, and David Thouless for the discovery of such topological phases of matter.

Dirac and Weyl fermions differ by their chirality. Just like our left and right hands, Weyl fermions occur in pairs, where one particle is a mirrored version of the other. The two partners are almost identical, yet they cannot be superimposed. Dirac fermions, by contrast, do not have this property.

One approach to create chirality in a material is to drive it with a laser beam. "It was realized about ten years ago that the so-called Floquet theory - a theory for laser-driven systems that oscillate periodically in time - allows us to engineer parameters and symmetries in materials that can change their topology," explains Michael Sentef, Emmy Noether group leader at the MPSD in Hamburg. Inducing chirality into a Dirac fermion material by combining those fermions with photons from the laser beam to form new quasiparticles can thus transform it into a Weyl fermion material.

In the present work, the team around Angel Rubio used high-level computational simulations of material properties to show how this optical transformation from Dirac fermions to Weyl fermions can be achieved in a real material – Na3Bi. This material is a so-called three-dimensional Dirac semimetal. It consists of layers of sodium and bismuth atoms that arrange to form a three-dimensional equivalent of graphene. This three-dimensionality is required for the transformation of Dirac into Weyl fermions to take place. It cannot happen in a two-dimensional sheet of graphene.

"The crucial challenge in this work was to take the ideas of Floquet theory and topology from the conceptual level of model systems to the world of real materials and to demonstrate that such non-equilibrium topological phase transitions can be realized in a materials science context," says Hannes Hübener, Marie Curie fellow at the University of the Basque Country in San Sebastián and lead author of the work.

From topological stability to ultrafast electronics

In particular, the authors could show how topological protection of the handedness of Weyl fermions arises and can be made more robust the stronger the laser field is. "We realized in our simulations that when we cranked up the field, the two different right- and left-handed Weyl fermions moved further apart from each other in the so-called momentum space, in which quasiparticles live," says Sentef. "Since right- and left-handed particles are antiparticles of each other, they have to come together to destroy each other. The separation thus protects them from getting destroyed, which means that we achieve topological stability of these quasiparticles."

The theoretical results suggest that experimentalists should be able to measure the transformation between Dirac and Weyl fermions in ultrafast laser experiments. One way of doing this is to use the photoelectric effect to eject electrons from the laser-driven material, a technique called pump-probe photoemission spectroscopy, which is available at the Max Planck Institute for the Structure and Dynamics of Matter under Otto-Hahn group leader Isabella Gierz and Director Andrea Cavalleri.

Angel Rubio, Director of the MPSD Theory Department, adds: "This work opens exciting new avenues to manipulate the properties of materials and molecules using fundamental light-matter interaction. It paves the way for ultimately controlling their behaviour at the nanoscale and with ultrafast switching cycles." The scientists even hope that there might be a way to stabilize the light-induced states for longer times while retaining the ability to switch them at terahertz or even faster frequencies. This may enable new ultrafast electronics for superfast computers in the future. [19]

First 'water-wave' laser created

Technion researchers have demonstrated, for the first time, that laser emissions can be created through the interaction of light and water waves. This "water-wave laser" could someday be used in tiny sensors that combine light waves, sound and water waves, or as a feature on microfluidic "lab-on-a-chip" devices used to study cell biology and to test new drug therapies.

For now, the water-wave laser offers a "playground" for scientists studying the interaction of light and fluid at a scale smaller than the width of a human hair, the researchers write in the new report, published last week in Nature Photonics.

The study was conducted by Technion-Israel Institute of Technology students Shmuel Kaminski, Leopoldo Martin, and Shai Maayani, under the supervision of Professor Tal Carmon, head of the Optomechanics Center at the Mechanical Engineering Faculty at Technion. Carmon said the study is the first bridge between two areas of research that were previously considered unrelated to one another: nonlinear optics and water waves.

A typical laser can be created when the electrons in atoms become "excited" by energy absorbed from an outside source, causing them to emit radiation in the form of laser light. Professor Carmon and his colleagues now show for the first time that water wave oscillations within a liquid device can also generate laser radiation.

The possibility of creating a laser through the interaction of light with water waves has not been examined, Carmon said, mainly due to the huge difference between the low frequency of water waves on the surface of a liquid (approximately 1,000 oscillations per second) and the high frequency of light wave oscillations (1014 oscillations per second). This frequency difference reduces the efficiency of the energy transfer between light and water waves, which is needed to produce the laser emission.

To compensate for this low efficiency, the researchers created a device in which an optical fiber delivers light into a tiny droplet of octane and water. Light waves and water waves pass through each other many times (approximately one million times) inside the droplet, generating the energy that leaves the droplet as the emission of the water-wave laser.

The interaction between the fiber optic light and the miniscule vibrations on the surface of the droplet are like an echo, the researchers noted, where the interaction of sound waves and the surface they pass through can make a single scream audible several times. In order to increase this echo effect in their device, the researchers used highly transparent, runny liquids, to encourage light and droplet interactions.

Furthermore, a drop of water is a million times softer than the materials used in current laser technology. The minute pressure applied by light can therefore cause droplet deformation that is a million times greater than in a typical optomechanical device, which may offer greater control of the laser's emissions and capabilities, the Technion scientists said. [18]

Capturing an elusive spectrum of light

Researchers led by EPFL have built ultra-high quality optical cavities for the elusive mid-infrared spectral region, paving the way for new chemical and biological sensors, as well as promising technologies.

The mid-infrared spectral window, referred to as "molecular fingerprint region," includes light wavelengths from 2.5 to 20 µm. It is a virtual goldmine for spectroscopy, chemical and biological sensing, materials science, and industry, as it is the range where many organic molecules can be detected. It also contains two ranges that allow transmission of signals through the atmosphere without distortion or loss. A way to harness the potential of the mid-infrared spectral window is to use optical cavities, which are micro-devices that confine light for extended amounts of time. However, such devices are currently unexplored due to technological challenges at this wavelength. Researchers led by EPFL have taken on this challenge and successfully shown that crystalline materials can be used to build ultra-high quality optical cavities for the mid-infrared spectral region, representing the highest value achieved for any type of mid-infrared resonator to date and setting a new record in the field. This unprecedented work is published in Nature Communications.

Caroline Lecaplain and Clément Javerzac-Galy from Tobias J. Kippenberg's lab at EPFL led the research effort, together with colleagues from the Russian Quantum Center. To make these ultra-high quality microcavities, the scientists used alkaline earth metal fluoride crystals that they polished manually. They developed uncoated chalcogenide tapered fibers to efficiently couple mid-infrared light from a continuous wave Quantum Cascade Laser (QCL) into their crystalline microcavities. Finally, cavity ring-down spectroscopy techniques enabled the team to unambiguously demonstrate ultra-high quality resonators deep in the mid-infrared spectral range.

Equally important, the scientists also show that the quality factor of the microcavity is limited by multi-phonon absorption. This is a phenomenon in which phonons – quasiparticles made of energy and vibrations in the cavity's crystal – simultaneously interact and disrupt light confinement.

This work marks a milestone in the field of mid-infrared materials as it opens for the first time access to ultra-high resonators. It is a significant step toward a compact frequency-stabilized laser in the mid-infrared, which could have a major impact on applications such as molecular spectroscopy, chemical sensing and bio-detection. [17]

Light detector with record-high sensitivity to revolutionize imaging

The research team led by Professor Hele Savin has developed a new light detector that can capture more than 96 percent of the photons covering visible, ultraviolet and infrared wavelengths.

"Present-day light detectors suffer from severe reflection losses as currently used antireflection coatings are limited to specific wavelengths and a fixed angle of incidence. Our detector captures light without such limitations by taking advantage of a nanostructured surface. Low incident angle is useful especially in scintillating x-ray sensors", Savin explains.

"We also addressed electrical losses present in traditional sensors that utilize semiconductor pn-junctions for light collection. Our detector does not need any dopants to collect light - instead we use an inversion layer generated by atomic layer deposited thin film."

The new concept for light detection kindled from the team's earlier research on nanostructured solar cells. Indeed, the nanostructure used in the light detector is similar to that used by the team a couple of years ago in their record-high efficiency black silicon solar cells.

The team has filed a patent application for the new light detector. The prototype detectors are currently being tested in imaging applications related to medicine and safety. The team is also continuously seeking new applications for their invention, especially among the ultraviolet and infrared ranges that would benefit from the superior spectral response.

The research results are published in Nature Photonics. [16]

Driven to diffraction

As anyone with an interest in photography will know, to get features such as a powerful zoom, you usually need a big camera. The reason is that most cameras rely on refraction, whereby the light passing through lenses slows down and changes direction. Focusing this refracted light requires a certain amount of space.

A promising route to smaller, powerful cameras built into smartphones and other devices is to design optical elements that manipulate light by diffraction-the bending of light around obstacles or through small gaps-instead of refraction.

Wolfgang Heidrich and co-workers at KAUST's Visual Computing Center and the University of British Columbia (UBC) in Canada are at the forefront of developing new diffractive optical elements (DOEs) that can be printed on to small, thin substrates. The team combines their carefully-designed DOEs with advanced computational techniques that can greatly enhance the images produced by such small optical devices.

Heidrich came to KAUST in 2014 from UBC, where he previously developed very high contrast displays for television sets.

"We developed the first consumer-ready display technology that had a major computational component, in the sense that the hardware itself was not useful without substantial computation," he says. "The target image would be sent to the device, and then the device would have to perform some fairly sophisticated algorithms on the image (in real time!) to produce the best image contrast. It really instilled in me the need for hardware-software co-design, where you develop optics, electronics and algorithms at the same time so that they fit together in the best possible way."

More recently, Heidrich and co-workers have applied the same approach to computational imaging for cameras. One major problem they are addressing, called chromatic aberration, will be familiar to anyone who has played with triangular prisms to produce a rainbow - different wavelengths change direction by varying amounts when they are refracted by lenses, resulting in incorrect color distributions in images.

Chromatic aberration is an even greater problem when light is manipulated by diffraction, so DOEs suffer a loss of color fidelity and blurring that depends on the color distribution of the incoming light. To combat this, Heidrich and his co-workers designed a thin, light-weight DOE called a diffractive achromat to balance the focusing contributions of different wavelengths1. Their results from testing this innovative new component were published in ACM Transactions on Graphics, the top journal destination for computer graphics studies.

"In a regular DOE lens, the focus will be near-perfect for a single design wavelength, and progressively blurred as you move away from that design wavelength," explains Heidrich. "The diffractive achromat sacrifices a little bit of sharpness for the design wavelength in exchange for more sharpness at all other wavelengths. Any remaining blur can then be removed computationally."

The researchers applied the same combination of cutting-edge optics with computer algorithms in a recent study published in Scientific Reports that could lead to extremely small zoom lenses2. They used computational algorithms to design two DOEs with particular shapes, such that when they are placed on top of each other, they represent a diffractive lens with a specific focal length.

Then comes the cleverest bit.

"As you rotate the two DOEs relative to each other, the focal length, or any other parameter of the optical system, can change smoothly," says Heidrich. "One obvious application is to produce zoom lenses that do not require the lens barrel to move in and out of the camera for zooming."

Heidrich believes the active research environment at KAUST has been invaluable for pursuing his recent goals. "I have been able to assemble an interdisciplinary team, for more ambitious projects that take our hardware-software co-design to the next level," he says. "What's more, all our diffractive optical elements were built in the KAUST Nanofabrication Core Lab, which allowed quick turn-around times for experiments."

Computational imaging is still in its infancy, and provides many avenues that Heidrich and his co-workers hope to explore in coming years. Perhaps most excitingly, because DOEs are so thin, they don't absorb much energy from light as it passes through. This means that DOEs could, in principle, be used to manipulate any part of the electromagnetic spectrum, from radio waves to gamma rays. [15]

New nanodevice shifts light's color at single-photon level

Converting a single photon from one color, or frequency, to another is an essential tool in quantum communication, which harnesses the subtle correlations between the subatomic properties of photons (particles of light) to securely store and transmit information. Scientists at the National Institute of Standards and Technology (NIST) have now developed a miniaturized version of a frequency converter, using technology similar to that used to make computer chips.

The tiny device, which promises to help improve the security and increase the distance over which next-generation quantum communication systems operate, can be tailored for a wide variety of uses, enables easy integration with other information-processing elements and can be mass produced.

The new nanoscale optical frequency converter efficiently converts photons from one frequency to the other while consuming only a small amount of power and adding a very low level of noise, namely background light not associated with the incoming signal.

Frequency converters are essential for addressing two problems. The frequencies at which quantum systems optimally generate and store information are typically much higher than the frequencies required to transmit that information over kilometer-scale distances in optical fibers. Converting the photons between these frequencies requires a shift of hundreds of terahertz (one terahertz is a trillion wave cycles per second).

A much smaller, but still critical, frequency mismatch arises when two quantum systems that are intended to be identical have small variations in shape and composition. These variations cause the systems to generate photons that differ slightly in frequency instead of being exact replicas, which the quantum communication network may require.

The new photon frequency converter, an example of nanophotonic engineering, addresses both issues, Qing Li, Marcelo Davanço and Kartik Srinivasan write in Nature Photonics. The key component of the chip-integrated device is a tiny ring-shaped resonator, about 80 micrometers in diameter (slightly less than the width of a human hair) and a few tenths of a micrometer in thickness. The shape and dimensions of the ring, which is made of silicon nitride, are chosen to enhance the inherent properties of the material in converting light from one frequency to another. The ring resonator is driven by two pump lasers, each operating at a separate frequency. In a scheme known as four-wave-mixing Bragg scattering, a photon entering the ring is shifted in frequency by an amount equal to the difference in frequencies of the two pump lasers.

Like cycling around a racetrack, incoming light circulates around the resonator hundreds of times before exiting, greatly enhancing the device's ability to shift the photon's frequency at low power and with low background noise. Rather than using a few watts of power, as typical in previous experiments, the system consumes only about a hundredth of that amount. Importantly, the added amount of noise is low enough for future experiments using single-photon sources.

While other technologies have been applied to frequency conversion, "nanophotonics has the benefit of potentially enabling the devices to be much smaller, easier to customize, lower power, and compatible with batch fabrication technology," said Srinivasan. "Our work is a first demonstration of a nanophotonic technology suitable for this demanding task of quantum frequency conversion." [14]

Quantum dots enhance light-to-current conversion in layered semiconductors

Harnessing the power of the sun and creating light-harvesting or light-sensing devices requires a material that both absorbs light efficiently and converts the energy to highly mobile electrical current. Finding the ideal mix of properties in a single material is a challenge, so scientists have been experimenting with ways to combine different materials to create "hybrids" with enhanced features.

In two just-published papers, scientists from the U.S. Department of Energy's Brookhaven National Laboratory, Stony Brook University, and the University of Nebraska describe one such approach that combines the excellent light-harvesting properties of quantum dots with the tunable electrical conductivity of a layered tin disulfide semiconductor. The hybrid material exhibited enhanced light-harvesting properties through the absorption of light by the quantum dots and their energy transfer to tin disulfide, both in laboratory tests and when incorporated into electronic devices. The research paves the way for using these materials in optoelectronic applications such as energy-harvesting photovoltaics, light sensors, and light emitting diodes (LEDs).

According to Mircea Cotlet, the physical chemist who led this work at Brookhaven Lab's Center for Functional Nanomaterials (CFN), a DOE Office of Science User Facility, "Two-dimensional metal dichalcogenides like tin disulfide have some promising properties for solar energy conversion and photodetector applications, including a high surface-to-volume aspect ratio. But no semiconducting material has it all. These materials are very thin and they are poor light absorbers. So we were trying to mix them with other nanomaterials like light-absorbing quantum dots to improve their performance through energy transfer."

One paper, just published in the journal ACS Nano, describes a fundamental study of the hybrid quantum dot/tin disulfide material by itself. The work analyzes how light excites the quantum dots (made of a cadmium selenide core surrounded by a zinc sulfide shell), which then transfer the absorbed energy to layers of nearby tin disulfide.

"We have come up with an interesting approach to discriminate energy transfer from charge transfer, two common types of interactions promoted by light in such hybrids," said Prahlad Routh, a graduate student from Stony Brook University working with Cotlet and co-first author of the ACS Nano paper. "We do this using single nanocrystal spectroscopy to look at how individual quantum dots blink when interacting with sheet-like tin disulfide. This straightforward method can assess whether components in such semiconducting hybrids interact either by energy or by charge transfer."

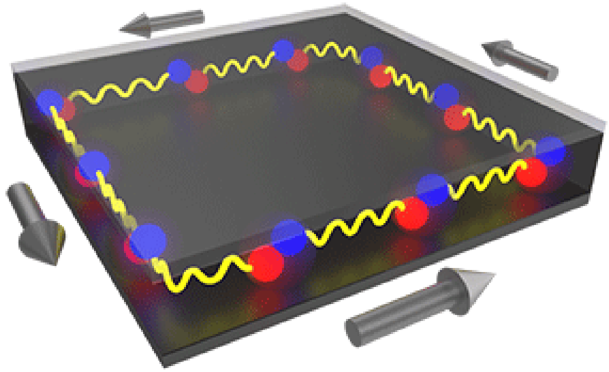
The researchers found that the rate for non-radiative energy transfer from individual quantum dots to tin disulfide increases with an increasing number of tin disulfide layers. But performance in laboratory tests isn't enough to prove the merits of potential new materials. So the scientists incorporated the hybrid material into an electronic device, a photo-field-effect-transistor, a type of photon detector commonly used for light sensing applications.

As described in a paper published online March 24 in Applied Physics Letters, the hybrid material dramatically enhanced the performance of the photo-field-effect transistors-resulting in a photocurrent response (conversion of light to electric current) that was 500 percent better than transistors made with the tin disulfide material alone.

"This kind of energy transfer is a key process that enables photosynthesis in nature," said Chang-Yong Nam, a materials scientist at Center for Functional Nanomaterials and co-corresponding author of the APL paper. "Researchers have been trying to emulate this principle in light-harvesting electrical devices, but it has been difficult particularly for new material systems such as the tin disulfide we studied. Our device demonstrates the performance benefits realized by using both energy transfer processes and new low-dimensional materials."

Cotlet concludes, "The idea of 'doping' two-dimensional layered materials with quantum dots to enhance their light absorbing properties shows promise for designing better solar cells and photodetectors." [13]

Quasiparticles dubbed topological polaritons make their debut in the theoretical world



Condensed-matter physicists often turn to particle-like entities called quasiparticles—such as excitons, plasmons, magnons—to explain complex phenomena. Now Gil Refael from the California Institute of Technology in Pasadena and colleagues report the theoretical concept of the topological polarition, or “topolariton”: a hybrid half-light, half-matter quasiparticle that has special topological properties and might be used in devices to transport light in one direction.

The proposed topolaritons arise from the strong coupling of a photon and an exciton, a bound state of an electron and a hole. Their topology can be thought of as knots in their gapped energy-band structure. At the edge of the systems in which topolaritons emerge, these knots unwind and allow the topolaritons to propagate in a single direction without back-reflection. In other words, the topolaritons cannot make U-turns. Back-reflection is a known source of detrimental feedback and loss in photonic devices. The topolaritons’ immunity to it may thus be exploited to build devices with increased performance.

The researchers describe a scheme to generate topolaritons that may be feasible to implement in common systems—such as semiconductor structures or atomically thin layers of compounds known as transition-metal dichalcogenides—embedded in photonic waveguides or microcavities. Previous approaches to make similar one-way photonic channels have mostly hinged on effects that are only applicable at microwave frequencies. Refael and co-workers’ proposal offers an avenue to make such “one-way photonic roads” in the optical regime, which despite progress has remained a challenging pursuit. [12]

'Matter waves' move through one another but never share space

Physicist Randy Hulet and colleagues observed a strange disappearing act during collisions between forms of Bose Einstein condensates called solitons. In some cases, the colliding clumps of matter appear to keep their distance even as they pass through each other. How can two clumps of matter pass through each other without sharing space? Physicists have documented a strange disappearing act by colliding Bose Einstein condensates that appear to keep their distance even as they pass through one another.

BECs are clumps of a few hundred thousand lithium atoms that are cooled to within one-millionth of a degree above absolute zero, a temperature so cold that the atoms march in lockstep and act as a single "matter wave." Solitons are waves that do not diminish, flatten out or change shape as they move through space. To form solitons, Hulet's team coaxed the BECs into a configuration where the attractive forces between lithium atoms perfectly balance the quantum pressure that tends to spread them out.

The researchers expected to observe the property that a pair of colliding solitons would pass though one another without slowing down or changing shape. However, they found that in certain collisions, the solitons approached one another, maintained a minimum gap between themselves, and then appeared to bounce away from the collision.

Hulet's team specializes in experiments on BECs and other ultracold matter. They use lasers to both trap and cool clouds of lithium gas to temperatures that are so cold that the matter's behavior is dictated by fundamental forces of nature that aren't observable at higher temperatures.

To create solitons, Hulet and postdoctoral research associate Jason Nguyen, the study's lead author, balanced the forces of attraction and repulsion in the BECs.

Cameras captured images of the tiny BECs throughout the process. In the images, two solitons oscillate back and forth like pendulums swinging in opposite directions. Hulet's team, which also included graduate student De Luo and former postdoctoral researcher Paul Dyke, documented thousands of head-on collisions between soliton pairs and noticed a strange gap in some, but not all, of the experiments.

Many of the events that Hulet's team measures occur in one-thousandth of a second or less. To confirm that the "disappearing act" wasn't causing a miniscule interaction between the soliton pairs -- an interaction that might cause them to slowly dissipate over time -- Hulet's team tracked one of the experiments for almost a full second.

The data showed the solitons oscillating back and fourth, winking in and out of view each time they crossed, without any measurable effect.

"This is great example of a case where experiments on ultracold matter can yield a fundamental new insight," Hulet said. "The phase-dependent effects had been seen in optical experiments, but there has been a misunderstanding about the interpretation of those observations." [11]

Photonic molecules

Working with colleagues at the Harvard-MIT Center for Ultracold Atoms, a group led by Harvard Professor of Physics Mikhail Lukin and MIT Professor of Physics Vladan Vuletic have managed to coax photons into binding together to form molecules – a state of matter that, until recently, had been purely theoretical. The work is described in a September 25 paper in Nature.

The discovery, Lukin said, runs contrary to decades of accepted wisdom about the nature of light. Photons have long been described as massless particles which don't interact with each other – shine two laser beams at each other, he said, and they simply pass through one another.

"Photonic molecules," however, behave less like traditional lasers and more like something you might find in science fiction – the light saber.

"Most of the properties of light we know about originate from the fact that photons are massless, and that they do not interact with each other," Lukin said. "What we have done is create a special type of medium in which photons interact with each other so strongly that they begin to act as though they have mass, and they bind together to form molecules. This type of photonic bound state has been discussed theoretically for quite a while, but until now it hadn't been observed. [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) $I = I_0 \sin^2 n\,\phi/2\ \mathbf{/}\ \sin^2 \phi/2$

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

(2) $I = n^2 I_0$

This gives us the idea of

(3) $M_p = n^2 M_e$

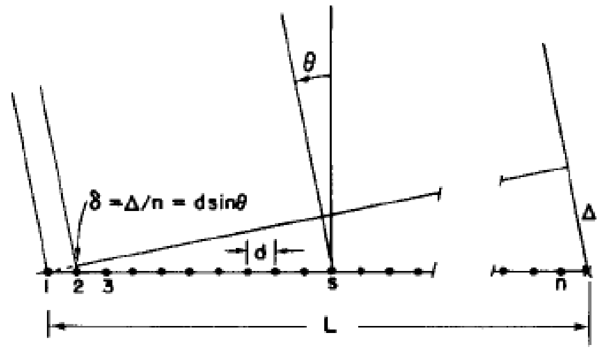


Fig. 30–3. A linear array of *n* equal oscillators, driven with phases $\alpha_s = s\alpha$.

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:

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

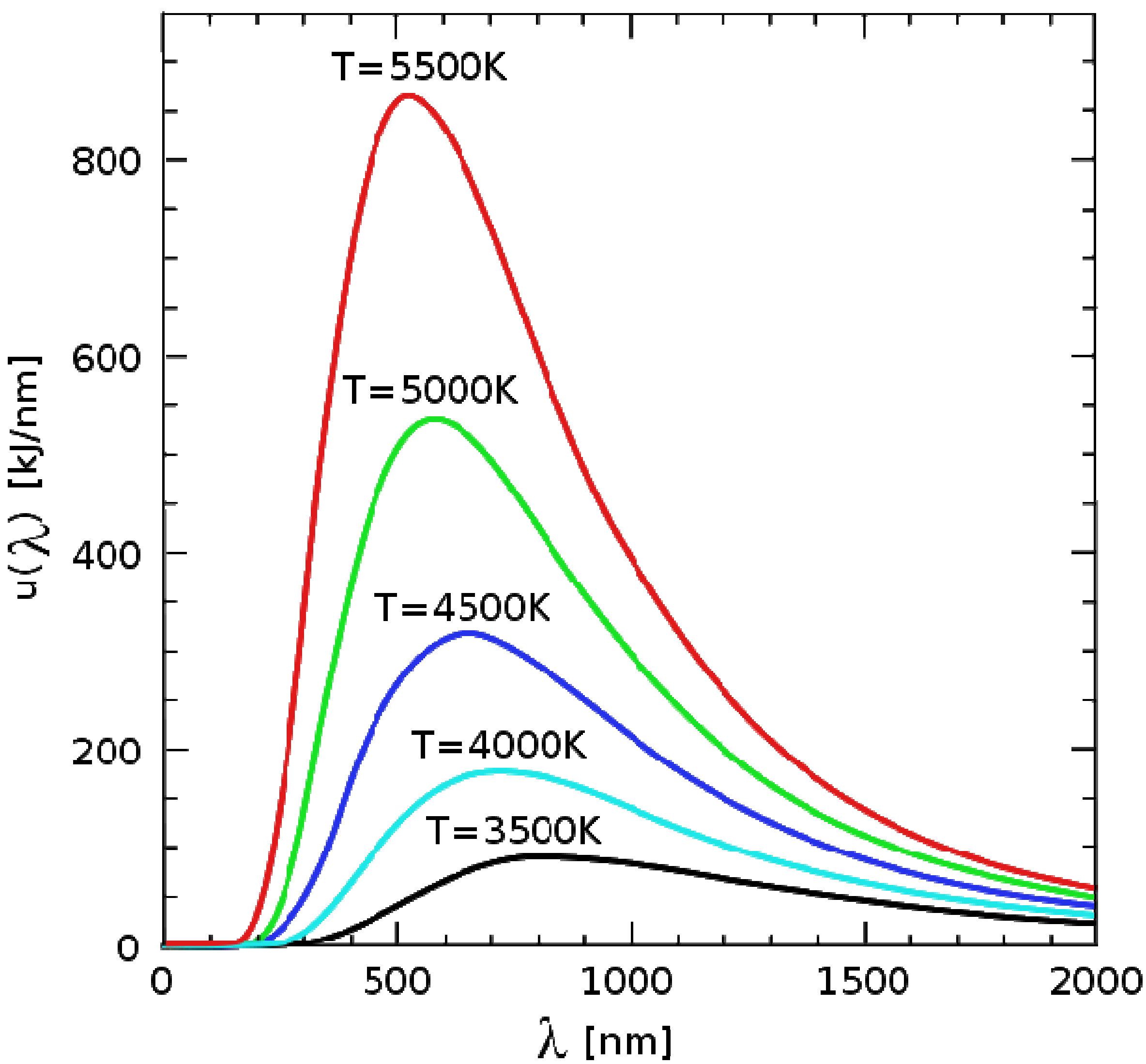


Figure 2. The distribution law for different T temperatures

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 $2.8977685(51) \times 10^{-3}$ 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 $\lambda\nu = c$, 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 proposed topolaritons arise from the strong coupling of a photon and an exciton, a bound state of an electron and a hole. Their topology can be thought of as knots in their gapped energy-band structure. At the edge of the systems in which topolaritons emerge, these knots unwind and allow the topolaritons to propagate in a single direction without back-reflection. In other words, the topolaritons cannot make U-turns. Back-reflection is a known source of detrimental feedback and loss in photonic devices. The topolaritons' immunity to it may thus be exploited to build devices with increased performance. [12]

Solitons are localized wave disturbances that propagate without changing shape, a result of a nonlinear interaction that compensates for wave packet dispersion. Individual solitons may collide, but a defining feature is that they pass through one another and emerge from the collision unaltered in shape, amplitude, or velocity, but with a new trajectory reflecting a discontinuous jump. This remarkable property is mathematically a consequence of the underlying integrability of the one-dimensional (1D) equations, such as the nonlinear Schrödinger equation, that describe solitons in a variety of wave contexts, including matter waves1, 2. Here we explore the nature of soliton collisions using Bose–Einstein condensates of atoms with attractive interactions confined to a quasi-1D waveguide. Using real-time imaging, we show that a collision between solitons is a complex event that differs markedly depending on the relative phase between the solitons. By controlling the strength of the nonlinearity we shed light on these fundamental features of soliton collisional dynamics, and explore the implications of collisions in the proximity of the crossover between one and three dimensions where the loss of integrability may precipitate catastrophic collapse. [10]

"It's a photonic interaction that's mediated by the atomic interaction," Lukin said. "That makes these two photons behave like a molecule, and when they exit the medium they're much more likely to do so together than as single photons." To build a quantum computer, he explained, researchers need to build a system that can preserve quantum information, and process it using quantum logic operations. The challenge, however, is that quantum logic requires interactions between individual quanta so that quantum systems can be switched to perform information processing. [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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