Terahertz Chips

Electromagnetic pulses lasting one millionth of a millionth of a second may hold the key to advances in medical imaging, communications and drug development. But the pulses, called terahertz waves, have long required elaborate and expensive equipment to use. [20]

A widely held understanding of electromagnetic radiation has been challenged in newly published research led at the University of Strathclyde. [19]

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

Wave of the future: Terahertz chips a new way of seeing through matter

Electromagnetic pulses lasting one millionth of a millionth of a second may hold the key to advances in medical imaging, communications and drug development. But the pulses, called terahertz waves, have long required elaborate and expensive equipment to use.

Now, researchers at Princeton University have drastically shrunk much of that equipment: moving from a tabletop setup with lasers and mirrors to a pair of microchips small enough to fit on a fingertip.

In two articles recently published in the IEEE Journal of Solid State Circuits, the researchers describe one microchip that can generate terahertz waves, and a second chip that can capture and read intricate details of these waves.

"The system is realized in the same silicon chip technology that powers all modern electronic devices from smartphones to tablets, and therefore costs only a few dollars to make on a large scale" said lead researcher Kaushik Sengupta, a Princeton assistant professor of electrical engineering.

Terahertz waves are part of the electromagnetic spectrum—the broad class of waves that includes radio, X-rays and visible light—and sit between the microwave and infrared light wavebands. The waves have some unique characteristics that make them interesting to science. For one, they pass through most non-conducting material, so they could be used to peer through clothing or boxes for security purposes, and because they have less energy than X-rays, they don't damage human tissue or DNA.

Terahertz waves also interact in distinct ways with different chemicals, so they can be used to characterize specific substances. Known as spectroscopy, the ability to use light waves to analyze material is one of the most promising—and the most challenging—applications of terahertz technology, Sengupta said.

To do it, scientists shine a broad range of terahertz waves on a target then observe how the waves change after interacting with it. The human eye performs a similar type of spectroscopy with visible light—we see a leaf as green because light in the green light frequency bounces off the chlorophyll-laden leaf.

The challenge has been that generating a broad range of terahertz waves and interpreting their interaction with a target requires a complex array of equipment such as bulky terahertz generators or ultrafast lasers. The equipment's size and expense make the technology impractical for most applications.

Researchers have been working for years to simplify these systems. In September, Sengupta's team reported a way to reduce the size of the terahertz generator and the apparatus that interprets the returning waves to a millimeter-sized chip. The solution lies in re-imaging how an antenna functions. When terahertz waves interact with a metal structure inside the chip, they create a complex distribution of electromagnetic fields that are unique to the incident signal. Typically, these subtle fields are ignored, but the researchers realized that they could read the patterns as a sort of signature to identify the waves. The entire process can be accomplished with tiny devices inside the microchip that read terahertz waves.

"Instead of directly reading the waves, we are interpreting the patterns created by the waves," Sengupta said. "It is somewhat like looking for a pattern of raindrops by the ripples they make in a pond."

Daniel Mittleman, a professor of engineering at Brown University, said the development was "a very innovative piece of work, and it potentially has a lot of impact." Mittleman, who is the vice chair of the International Society for Infrared Millimeter and Terahertz Waves, said scientists still have work to do before the terahertz band can begin to be used in everyday devices, but the developments are promising.

"It is a very big puzzle with many pieces, and this is just one, but it is a very important one," said Mittleman, who is familiar with the work but had no role in it.

On the terahertz-generation end, much of the challenge is creating a wide range of wavelengths within the terahertz band, particularly in a microchip. The researchers realized they could overcome the problem by generating multiple wavelengths on the chip. They then used precise timing to combine these wavelengths and create very sharp terahertz pulses.

In an article published Dec. 14 in the IEEE Journal of Solid State Circuits, the researchers explained how they created a chip to generate the terahertz waves. The next step, the researchers said, is to extend the work farther along the terahertz band. "Right now we are working with the lower part of the terahertz band," said Xue Wu, a Princeton doctoral student in electrical engineering and an author on both papers.

"What can you do with a billion transistors operating at terahertz frequencies?" Sengupta asked. "Only by re-imagining these complex electromagnetic interactions from fundamental principles can we invent game-changing new technology." [20]

Light source discovery 'challenges basic assumption' of physics

A widely held understanding of electromagnetic radiation has been challenged in newly published research led at the University of Strathclyde.

The study found that the normal direct correspondence between the bandwidths of the current source and emitted radiation can be broken. This was achieved by extracting narrowband radiation with high efficiency, without making the oscillation of the current narrowband.

The finding produced narrowband light sources in media where electromagnetic radiation would not normally be possible. It makes for a powerful tool for scientists that enables them to understand the intricacies of how materials, or even biological molecules, behave under different conditions, which has a major impact on people's lives through the development of new products and medical treatments.

The research, published in Scientific Reports, also involved researchers at the Ulsan National Institute of Science and Technology (UNIST) and the Gwangju Institute of Science and Technology (GIST), both in South Korea.

Professor Dino Jaroszynski, of Strathclyde's Department of Physics, led the study. He said: "Coherent light sources such as lasers have many uses, from communication to probing the structure of matter. The simplest source of coherent electromagnetic radiation is an oscillating electric current in an antenna. However, there are many other devices are based on these basic laws of physics, such as the free-electron laser, which produces coherent X-ray radiation, or magnetrons found in microwave ovens.

"Our study has shown that some common media with interesting optical properties can be taken advantage of if we imbed, or bury, an oscillating current source in them. Media such as plasma, semiconductors and photonic structures have a 'cut-off', where propagation of electromagnetic radiation with frequencies lower than the 'cut-off' frequency is not possible; we noticed that the radiation impedance is increased at the cut-off.

"One consequence of this is that, for a broadband current source immersed in this type of dispersive medium, the cut-off frequency 'mode' is selectively enhanced due to Ohm's law, resulting in narrow bandwidth emission. What is curious is that novel physics should still be hidden in the classical cut-off behaviour; in our research, we uncovered a hidden face of the cut-off and realised a new paradigm of narrowband light sources in media that would not usually allow electromagnetic radiation to propagate. This is a remarkably simple idea based on straightforward physics theory that seems to have been overlooked.

"This is a very exciting theoretical discovery that comes out of a very fruitful cross-continental collaboration. It shows that we should always keep an open mind and question even very basic assumptions. We hope to demonstrate this phenomenon at the Strathclyde-based Scottish Centre for the Application of Plasma-based Accelerators; there are numerous applications of electromagnetic radiation and the proposed source should have a large impact if we are able to demonstrate it experimentally."

Professor Min Sup Hur at UNIST, Republic of South Korea, who leads the work from UNIST, said: "This new discovery is scientifically interesting, because it leads us to see the phenomenon of electromagnetic radiation from a completely different viewpoint. We hope the fruitful international collaboration, which brought us to this theoretical discovery, will continue with the experimental demonstration of the idea."

Modern light sources, or, more generally, electromagnetic sources used as scientific tools require good coherency, monochromaticity, and high emission power. Coherency and narrow bandwidth - or monochromaticity - are important properties of electromagnetic radiation that allow it to be used to observe changes in the structure of materials subject to stimuli, such as a short intense laser pulse; material properties are deduced from changes that are made apparent in pump-probe studies. An analogy would be to making a movie by assembling many time lapse snapshots to animate the changes that are occurring in the material after it has been stimulated.

The main challenge is making high power sources of electromagnetic radiation monochromatic. This is often done by making the oscillating current narrowband or filtering the spectrum, which is extremely inefficient. It is complicated, and can be expensive, to reduce the bandwidth of a current source while maintaining or increasing its radiated power.

The Research Excellence Framework 2014, the comprehensive rating of UK universities' research, ranked the University of Strathclyde's Physics research first in the UK, with 96% of output assessed as world-leading or internationally excellent. [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."

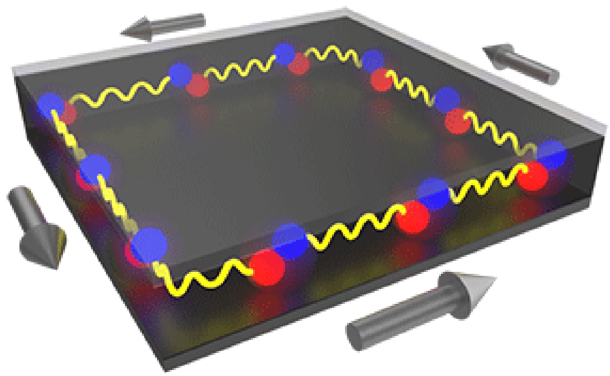
The researchers found that the rate for non-radiative energy transfer from individual quantum dots to tin disulfide increases with an increasing number of tin disulfide layers. But performance in laboratory tests isn't enough to prove the merits of potential new materials. So the scientists incorporated 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) $I = I_0 \sin^2 n\,\phi/2\ /\ \sin^2 \phi/2$

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

(2) $I = n^2 I_0$

This gives us the idea of

(3) $M_p = n^2 M_e$

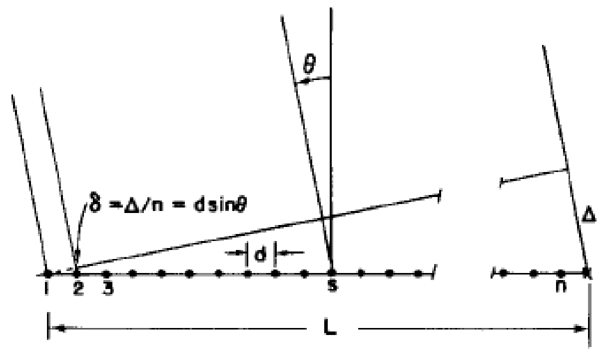


Fig. 30–3. A linear array of *n* equal oscillators, driven with phases $\alpha_s = s\alpha$.

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:

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

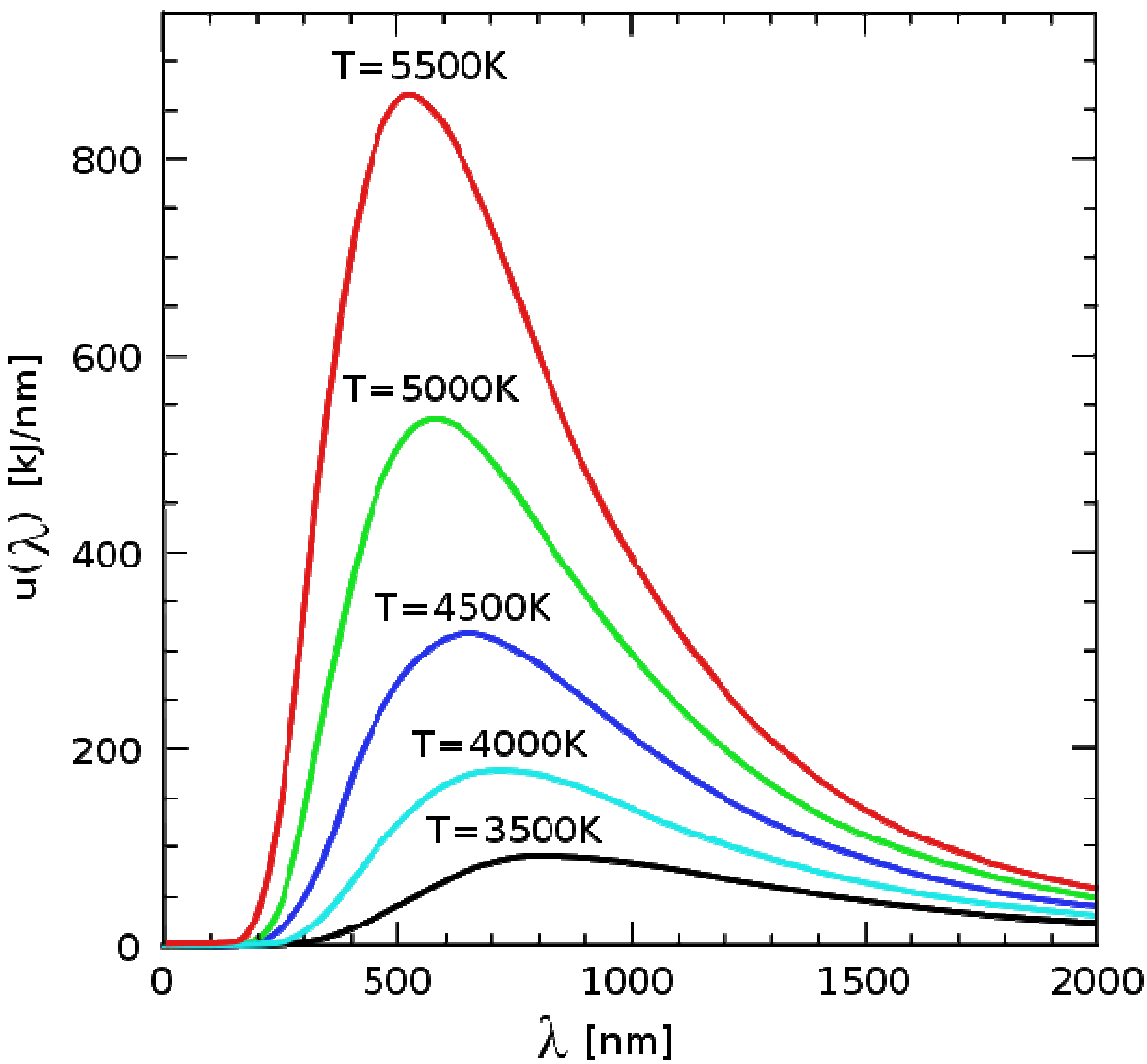


Figure 2. The distribution law for different T temperatures

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) $$\lambda_{\mathrm{max}} = \frac{b}{T}$$

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 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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