Universal Quantum Gate

Scientists have now developed a universal quantum gate, which could become the key component in a quantum computer. [14]

Using a small quantum system consisting of three superconducting qubits, researchers at UC Santa Barbara and Google have uncovered a link between aspects of classical and quantum physics thought to be unrelated: classical chaos and quantum entanglement. Their findings suggest that it would be possible to use controllable quantum systems to investigate certain fundamental aspects of nature. [13]

Bowtie-shaped nanoparticles made of silver may help bring the dream of quantum computing and quantum information processing closer to reality. These nanostructures, created at the Weizmann Institute of Science and described recently in Nature Communications, greatly simplify the experimental conditions for studying quantum phenomena and may one day be developed into crucial components of quantum devices. [12]

A source of single photons that meets three important criteria for use in quantum-information systems has been unveiled in China by an international team of physicists. Based on a quantum dot, the device is an efficient source of photons that emerge as solo particles that are indistinguishable from each other. The researchers are now trying to use the source to create a quantum computer based on "boson sampling". [11]

With the help of a semiconductor quantum dot, physicists at the University of Basel have developed a new type of light source that emits single photons. For the first time, the researchers have managed to create a stream of identical photons. [10]

Optical photons would be ideal carriers to transfer quantum information over large distances. Researchers envisage a network where information is processed in certain nodes and transferred between them via photons. [9]

While physicists are continually looking for ways to unify the theory of relativity, which describes large-scale phenomena, with quantum theory, which describes small-scale phenomena, computer scientists are searching for technologies to build the quantum computer using Quantum Information.

In August 2013, the achievement of "fully deterministic" quantum teleportation, using a hybrid technique, was reported. On 29 May 2014, scientists announced a reliable way of transferring data by quantum teleportation. Quantum teleportation of data had been done before but with highly unreliable methods.

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.

The Planck Distribution Law of the electromagnetic oscillators explains the electron/proton mass rate and the Weak and Strong Interactions by the diffraction patterns. The Weak Interaction changes the diffraction patterns by moving the electric charge from one side to the other side of the diffraction pattern, which violates the CP and Time reversal symmetry.

The diffraction patterns and the locality of the self-maintaining electromagnetic potential explains also the Quantum Entanglement, giving it as a natural part of the Relativistic Quantum Theory and making possible to build the Quantum Computer with the help of Quantum Information.

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Preface

While physicists are continually looking for ways to unify the theory of relativity, which describes large-scale phenomena, with quantum theory, which describes small-scale phenomena, computer scientists are searching for technologies to build the quantum computer.

Australian engineers detect in real-time the quantum spin properties of a pair of atoms inside a silicon chip, and disclose new method to perform quantum logic operations between two atoms. [5]

Quantum entanglement is a physical phenomenon that occurs when pairs or groups of particles are generated or interact in ways such that the quantum state of each particle cannot be described independently – instead, a quantum state may be given for the system as a whole. [4]

I think that we have a simple bridge between the classical and quantum mechanics by understanding the Heisenberg Uncertainty Relations. It makes clear that the particles are not point like but have a dx and dp uncertainty.

Researchers Develop A Universal Quantum Gate

Light particles completely ignore each other. In order that these particles can nevertheless switch each other when processing quantum information, researchers at the Max Planck Institute of Quantum Optics in Garching have now developed a universal quantum gate. Quantum gates are essential elements of a quantum computer. Switching them with photons, i.e. light particles, would have practical advantages over operating them with other carriers of quantum information.

The light-saber fights of the Jedi and Sith in the Star Wars saga may well suggest something different, but light beams do not notice each other. No matter how high their intensity, they cut through each other without hindrance. When individual light particles meet, as is necessary for some applications of quantum information technology, nothing at all happens. Photons can therefore not switch each other just like that, as would have to be the case if one wanted to use them to operate a quantum gate, the elementary computing unit of a quantum computer.

A quantum computer can master some tasks, such as searching through databases, much faster than conventional computers. Physicists have already developed quantum gates for the super-computers of the future, for example by using nitrogen atoms contained in diamonds as impurities as the smallest computing unit. But “to have a quantum computer compute with photons would have practical advantages,” says Stephan Ritter, who leads a Research Group in Gerhard Rempe’s Division at the Max Planck Institute of Quantum Optics. “This is because quantum information has to be in the form of photons in order to be transmitted over large distances. If we can use photons to process it as well, we do not have to transfer it to other carriers, such as atoms, in order to compute with it.”

An atom in a resonator mediates between light particles

In order for photons to sense each other’s presence in the first place, let alone switch each other, they need mediators. In the experiments being conducted by Stephan Ritter’s team of physicists, this mediating role is taken on by a single atom in a resonator. The resonator consists of two mirrors 0.5 mm apart. The Garching-based researchers use a laser beam to trap the atom in the resonator.

For their experiments, the scientists now need two photons each carrying one qubit. A qubit is the quantum mechanical equivalent of the bit of a conventional computer. It can, however, not only encode the zero and the one, but assume all possible states in between as well. The researchers write the states of the two qubits into the polarization of the two light particles, i.e. into the direction of oscillation of the electromagnetic waves.

The Max Planck physicists send the two photons, one shortly after the other, onto the system of atom and resonator. The first photon thereby transfers information to the atom by changing its state – but only if the photon has the right polarization. This change then has an effect on the polarization of the second photon when it impinges onto the system of atom and resonator a short time later.

The quantum gate operates in a deterministic way

"Our system only becomes a universal quantum gate because the second photon can also transfer information onto the first photon, however," says Bastian Hacker, who conducted the experiments as part of his doctoral thesis. To this end, the scientists initially store the two photons in an optical fiber more than one kilometer in length after the light particles have been reflected at the resonator. At the same time, they conduct a measurement on the atom, which can also affect the polarization state of the two photons due to the surprising properties of quantum mechanics. As is the case with a conventional bit, there are only two possible measurement results. They provide the researchers with reliable information about which rotation of the polarization of the first photon they can use to complete the gate operation.

"Our quantum gate operates in a deterministic way," says Stephan Ritter. This means that the scientists can reliably predict which changes the light particles should experience in the quantum gate depending on the original polarization of the photons fed in. In addition, the gate carries out these operations on all photons which impinge on the resonator with the trapped atom – at least in principle. In reality, unavoidable technical shortcomings decrease the efficiency of the quantum gate as well as the precision of its operations. However, the researchers already have some ideas about how they can improve the two characteristics of the quantum gate: by using mirrors with lower losses, for example, or a storage device for the photons which is more efficient than an optical fibre. In other implementations of quantum gates between photons with which physicists have already experimented, the errors are inherent, however, because chance always plays a role here.

Two experiments demonstrate how reliable the quantum gate is

The Garching-based researchers have conducted two experiments to demonstrate how reliably their quantum gate already operates. Which operations the quantum gate executes here depends only on how the two input photons are polarized.

In one experiment, the researchers circularly polarize the first photon so that its direction of oscillation rotates either clockwise or counter-clockwise. The second photon is linearly polarized, i.e. so that it oscillates in a horizontal or vertical plane. On a photon pair with these input states, the quantum gate acts like a CNOT operation, where the first qubit controls the second one. This is because, depending on the direction in which the first photon rotates, the quantum gate flips the polarization of the second photon – from the vertical to the horizontal plane, for example – or not. CNOT gates are essential for a quantum computer, because they can be used to execute all logic operations.

For the second experiment, the researchers in Garching polarize both photons linearly. Fed with such input states, the quantum gate entangles the two photons.

Entangled photons can no longer be described independently of each other, but only with a common state – no matter how great the distance between the two light particles. As much as entanglement puts our imagination to the test, for the quantum computer it is an indispensable ingredient like the CNOT gate. "Only the entanglement of qubits allows the strength of the quantum computer to be unfolded," says Stephan Welte, who also contributed crucial work to the experiments as part of his doctoral thesis.

The atom in the resonator as the key element of a quantum computer

"With the quantum gate, we now have a key element for an optical quantum computer," says Gerhard Rempe, Director at the Max Planck Institute in Garching. It will be a while before such a quantum computer completes some computing tasks at a speed which will outclass any conventional computer, however; not least because this requires the quantum gate to compute more reliably. Nevertheless, Gerhard Rempe already has definite ideas about how such a super-computer could be operated with an atom in the resonator. This would not require many of these systems, each of which can quite easily fill a laboratory. "The logic operations can be carried out one after the other with a single atom in a resonator," says Gerhard Rempe.

The European Commission obviously also believes that these quantum technology concepts have a future. It plans to invest one billion euros into their development over a period of approx. ten years. This funding could also speed up the process of realizing the superfast quantum computer – which is also what Stephan Ritter and his colleagues in Garching are hoping. [14]

Researchers blur the line between classical and quantum physics by connecting chaos and entanglement

Using a small quantum system consisting of three superconducting qubits, researchers at UC Santa Barbara and Google have uncovered a link between aspects of classical and quantum physics thought to be unrelated: classical chaos and quantum entanglement. Their findings suggest that it would be possible to use controllable quantum systems to investigate certain fundamental aspects of nature.

"It's kind of surprising because chaos is this totally classical concept—there's no idea of chaos in a quantum system," Charles Neill, a researcher in the UCSB Department of Physics and lead author of a paper that appears in Nature Physics. "Similarly, there's no concept of entanglement within classical systems. And yet it turns out that chaos and entanglement are really very strongly and clearly related."

Initiated in the 15th century, classical physics generally examines and describes systems larger than atoms and molecules. It consists of hundreds of years' worth of study including Newton's laws of motion, electrodynamics, relativity, thermodynamics as well as chaos theory—the field that studies the behavior of highly sensitive and unpredictable systems. One classic example of chaos theory is the weather, in which a relatively small change in one part of the system is enough to foil predictions—and vacation plans—anywhere on the globe.

At smaller size and length scales in nature, however, such as those involving atoms and photons and their behaviors, classical physics falls short. In the early 20th century quantum physics emerged, with its seemingly counterintuitive and sometimes controversial science, including the notions of superposition (the theory that a particle can be located in several places at once) and entanglement (particles that are deeply linked behave as such despite physical distance from one another).

And so began the continuing search for connections between the two fields.

All systems are fundamentally quantum systems, according Neill, but the means of describing in a quantum sense the chaotic behavior of, say, air molecules in an evacuated room, remains limited.

Imagine taking a balloon full of air molecules, somehow tagging them so you could see them and then releasing them into a room with no air molecules, noted co-author and UCSB/Google researcher Pedram Roushan. One possible outcome is that the air molecules remain clumped together in a little cloud following the same trajectory around the room. And yet, he continued, as we can probably intuit, the molecules will more likely take off in a variety of velocities and directions, bouncing off walls and interacting with each other, resting after the room is sufficiently saturated with them.

"The underlying physics is chaos, essentially," he said. The molecules coming to rest—at least on the macroscopic level—is the result of thermalization, or of reaching equilibrium after they have achieved uniform saturation within the system. But in the infinitesimal world of quantum physics, there is still little to describe that behavior. The mathematics of quantum mechanics, Roushan said, do not allow for the chaos described by Newtonian laws of motion.

To investigate, the researchers devised an experiment using three quantum bits, the basic computational units of the quantum computer. Unlike classical computer bits, which utilize a binary system of two possible states (e.g., zero/one), a qubit can also use a superposition of both states (zero and one) as a single state.

Additionally, multiple qubits can entangle, or link so closely that their measurements will automatically correlate. By manipulating these qubits with electronic pulses, Neill caused them to interact, rotate and evolve in the quantum analog of a highly sensitive classical system.

The result is a map of entanglement entropy of a qubit that, over time, comes to strongly resemble that of classical dynamics—the regions of entanglement in the quantum map resemble the regions of chaos on the classical map. The islands of low entanglement in the quantum map are located in the places of low chaos on the classical map.

"There's a very clear connection between entanglement and chaos in these two pictures," said Neill. "And, it turns out that thermalization is the thing that connects chaos and entanglement. It turns out that they are actually the driving forces behind thermalization.

"What we realize is that in almost any quantum system, including on quantum computers, if you just let it evolve and you start to study what happens as a function of time, it's going to thermalize," added Neill, referring to the quantum-level equilibration. "And this really ties together the intuition between classical thermalization and chaos and how it occurs in quantum systems that entangle."

The study's findings have fundamental implications for quantum computing. At the level of three qubits, the computation is relatively simple, said Roushan, but as researchers push to build increasingly sophisticated and powerful quantum computers that incorporate more qubits to study highly complex problems that are beyond the ability of classical computing—such as those in the realms of machine learning, artificial intelligence, fluid dynamics or chemistry—a quantum processor optimized for such calculations will be a very powerful tool.

"It means we can study things that are completely impossible to study right now, once we get to bigger systems," said Neill. [13]

Bowtie-shaped nanostructures may advance the development of quantum devices

Bowtie-shaped nanoparticles made of silver may help bring the dream of quantum computing and quantum information processing closer to reality. These nanostructures, created at the Weizmann Institute of Science and described recently in Nature Communications, greatly simplify the experimental conditions for studying quantum phenomena and may one day be developed into crucial components of quantum devices.

The research team led by Prof. Gilad Haran of Weizmann's Chemical Physics Department - postdoctoral fellow Dr. Kotni Santhosh, Dr. Ora Bitton of Chemical Research Support and Prof. Lev Chuntonov of the Technion-Israel Institute of Technology - manufactured two-dimensional bowtie-shaped silver nanoparticles with a minuscule gap of about 20 nanometers (billionths of a meter) in the center. The researchers then dipped the "bowties" in a solution containing quantum dots, tiny semiconductor particles that can absorb and emit light, each measuring six to eight nanometers across. In the course of the dipping, some of the quantum dots became trapped in the bowtie gaps.

Under exposure to light, the trapped dots became "coupled" with the bowties - a scientific term referring to the formation of a mixed state, in which a photon in the bowtie is shared, so to speak, with the quantum dot. The coupling was sufficiently strong to be observed even when the gaps contained a single quantum dot, as opposed to several. The bowtie nanoparticles could thus be prompted to switch from one state to another: from a state without coupling to quantum dots, before exposure to light, to the mixed state characterized by strong coupling, following such exposure.

Therefore, the ability to control the coupling of quantum dots may one day be employed in the manufacture of switches for computing or encryption devices relying on quantum phenomena, that is, those operating at the level of photons and single quantum systems, such as atoms, molecules or quantum dots. Because such phenomena open up possibilities unavailable on the macroscopic scale - for example, performing multiple computations simultaneously - quantum devices are expected to be vastly more powerful than today's electronic computers and encryption systems.

Says Prof. Haran: "We've made a first step toward creating quantum switches using our coupling method. Much research needs to be done before the method can be incorporated into actual devices, but as a matter of principle, our system is relatively easy to generate and, most importantly, can function at room temperature.

We are currently working to fabricate even smaller bowtie particles and to render the coupling stronger and reversible."

The Weizmann scientists managed to design their bowtie system thanks to advances in nanotechnology - including electron beam lithography, used to fabricate the bowties and to facilitate the introduction of quantum dots into their gaps - and the advent of computational programs providing data analysis that previously required a massive effort on the part of theoreticians. They also relied on the recently improved understanding of electron oscillations triggered by light in metals, which constitute the physical source of the coupling between the bowtie nanoparticles and the quantum dots: Such oscillations are known to be strongest on the metal surface. In the new bowtie-shaped particles, the electromagnetic field generated by these oscillations is extremely concentrated because it is focused to the central, narrow portion of the bowtie, much as light is concentrated when focused into a narrow beam.

The high concentration ensures tight control over the coupling, and this control, in turn, is essential for potential future quantum applications. None of the systems built in the past to study quantum interactions between light and matter operated on such a small scale or were able to reduce experiments to the level of individual quantum dots, as was done in the Weizmann study. [12]

Single-photon source is efficient and indistinguishable

Devices that emit one – and only one – photon on demand play a central role in light-based quantum-information systems. Each photon must also be emitted in the same quantum state, which makes each photon indistinguishable from all the others. This is important because the quantum state of the photon is used to carry a quantum bit (qubit) of information.

Quantum dots are tiny pieces of semiconductor that show great promise as single-photon sources. When a laser pulse is fired at a quantum dot, an electron is excited between two distinct energy levels. The excited state then decays to create a single photon with a very specific energy. However, this process can involve other electron excitations that result in the emission of photons with a wide range of energies – photons that are therefore not indistinguishable.

Exciting dots

This problem can be solved by exciting the quantum dot with a pulse of light at the same energy as the emitted photon. This is called resonance fluorescence, and has been used to create devices that are very good at producing indistinguishable single photons. However, this process is inefficient, and only produces a photon about 6% of the time.

Now, Chaoyang Lu, Jian-Wei Pan and colleagues at the University of Science and Technology of China have joined forces with researchers in Denmark, Germany and the UK to create a resonance-fluorescence-based source that emits a photon 66% of the time when it is prompted by a laser pulse. Of these photons, 99.1% are solo and 98.5% are in indistinguishable quantum states – with both figures of merit being suitable for applications in quantum-information systems.

Lu told physicsworld.com that nearly all of the laser pulses that strike the source produce a photon, but about 34% of these photons are unable to escape the device. The device was operated at a laser-pulse frequency of 81 MHz and a pulse power of 24 nW, which is a much lower power requirement than other quantum-dot-based sources.

Quantum sandwich

The factor-of-ten improvement in efficiency was achieved by sandwiching a quantum dot in the centre of a "micropillar" created by stacking 40 disc-like layers (see figure). Each layer is a "distributed Bragg reflector", which is a pair of mirrors that together have a thickness of one quarter the wavelength of the emitted photons.

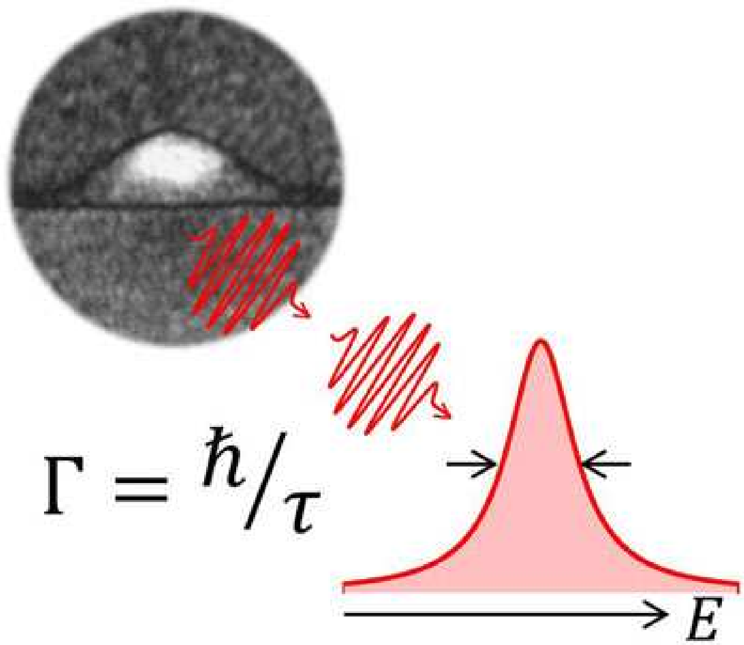
The micropillar is about 2.5 µm in diameter and about 10 µm tall, and it allowed the team to harness the "Purcell effect", whereby the rate of fluorescence is increased significantly when the emitter is placed in a resonant cavity.

Lu says that the team is already thinking about how the photon sources could be used to perform boson sampling (see "'Boson sampling' offers shortcut to quantum computing"). This involves a network of beam splitters that converts one set of photons arriving at a number of parallel input ports into a second set leaving via a number of parallel outputs. The "result" of the computation is the probability that a certain input configuration will lead to a certain output. This result cannot be easily calculated using a conventional computer, and this has led some physicists to suggest that boson sampling could be used to solve practical problems that would take classical computers vast amounts of time to solve.

Other possible applications for the source are the quantum teleportation of three properties of a quantum system – the current record is two properties and is held by Lu and Pan – or quantum cryptography.

The research is described in Physical Review Letters. [11]

Semiconductor quantum dots as ideal single-photon source



A single-photon source never emits two or more photons at the same time. Single photons are important in the field of quantum information technology where, for example, they are used in quantum computers. Alongside the brightness and robustness of the light source, the indistinguishability of the photons is especially crucial. In particular, this means that all photons must be the same color. Creating such a source of identical single photons has proven very difficult in the past.

However, quantum dots made of semiconductor materials are offering new hope. A quantum dot is a collection of a few hundred thousand atoms that can form itself into a semiconductor under certain conditions. Single electrons can be captured in these quantum dots and locked into a very small area. An individual photon is emitted when an engineered quantum state collapses.

Noise in the semiconductor

A team of scientists led by Dr. Andreas Kuhlmann and Prof. Richard J. Warburton from the University of Basel have already shown in past publications that the indistinguishability of the photons is reduced by the fluctuating nuclear spin of the quantum dot atoms. For the first time ever, the scientists have managed to control the nuclear spin to such an extent that even photons sent out at very large intervals are the same color.

Quantum cryptography and quantum communication are two potential areas of application for single-photon sources. These technologies could make it possible to perform calculations that are far beyond the capabilities of today's computers. [10]

How to Win at Bridge Using Quantum Physics

Contract bridge is the chess of card games. You might know it as some stuffy old game your grandparents play, but it requires major brainpower, and preferably an obsession with rules and strategy. So how to make it even geekier? Throw in some quantum mechanics to try to gain a competitive advantage. The idea here is to use the quantum magic of entangled photons–which are essentially twins, sharing every property–to transmit two bits of information to your bridge partner for the price of one. Understanding how to do this is not an easy task, but it will help elucidate some basic building blocks of quantum information theory. It's also kind of fun to consider whether or not such tactics could ever be allowed in professional sports. [6]

Quantum Information

In quantum mechanics, quantum information is physical information that is held in the "state" of a quantum system. The most popular unit of quantum information is the qubit, a two-level quantum system. However, unlike classical digital states (which are discrete), a two-state quantum system can actually be in a superposition of the two states at any given time.

Quantum information differs from classical information in several respects, among which we note the following:

However, despite this, the amount of information that can be retrieved in a single qubit is equal to one bit. It is in the processing of information (quantum computation) that a difference occurs.

The ability to manipulate quantum information enables us to perform tasks that would be unachievable in a classical context, such as unconditionally secure transmission of information. Quantum information processing is the most general field that is concerned with quantum information. There are certain tasks which classical computers cannot perform "efficiently" (that is, in polynomial time) according to any known algorithm. However, a quantum computer can compute the answer to some of these problems in polynomial time; one well-known example of this is Shor's factoring algorithm. Other algorithms can speed up a task less dramatically - for example, Grover's search algorithm which gives a quadratic speed-up over the best possible classical algorithm.

Quantum information, and changes in quantum information, can be quantitatively measured by using an analogue of Shannon entropy. Given a statistical ensemble of quantum mechanical systems with the density matrix S, it is given by.

Many of the same entropy measures in classical information theory can also be generalized to the quantum case, such as the conditional quantum entropy. [7]

Heralded Qubit Transfer

Optical photons would be ideal carriers to transfer quantum information over large distances. Researchers envisage a network where information is processed in certain nodes and transferred between them via photons. However, inherent losses in long-distance networks mean that the information transfer is subject to probabilistic errors, making it hard to know whether the transfer of a qubit of information has been successful. Now Gerhard Rempe and colleagues from the Max Planck Institute for Quantum Optics in Germany have developed a new protocol that solves this problem through a strategy that "heralds" the accurate transfer of quantum information at a network node.

The method developed by the researchers involves transferring a photonic qubit to an atomic qubit trapped inside an optical cavity. The photon-atom quantum information transfer is initiated via a quantum "logic-gate" operation, performed by reflecting the photon from the atom-cavity system, which creates an entangled atom-photon state. The detection of the reflected photon then collapses the atom into a definite state. This state can be one of two possibilities, depending on the photonic state detected: Either the atom is in the initial qubit state encoded in the photon and the transfer process is complete, or the atom is in a rotated version of this state. The authors were able to show that the roles of the atom and photon could be reversed. Their method could thus be used as a quantum memory that stores (photon-to-atom state transfer) and recreates (atom-to-photon state transfer) a single-photon polarization qubit. [9]

Quantum Teleportation

Quantum teleportation is a process by which quantum information (e.g. the exact state of an atom or photon) can be transmitted (exactly, in principle) from one location to another, with the help of classical communication and previously shared quantum entanglement between the sending and receiving location. Because it depends on classical communication, which can proceed no faster than the speed of light, it cannot be used for superluminal transport or communication of classical bits. It also cannot be used to make copies of a system, as this violates the no-cloning theorem. Although the name is inspired by the teleportation commonly used in fiction, current technology provides no possibility of anything resembling the fictional form of teleportation. While it is possible to teleport one or more qubits of information between two (entangled) atoms, this has not yet been achieved between molecules or anything larger. One may think of teleportation either as a kind of transportation, or as a kind of communication; it provides a way of transporting a qubit from one location to another, without having to move a physical particle along with it.

The seminal paper first expounding the idea was published by C. H. Bennett, G. Brassard, C. Crépeau, R. Jozsa, A. Peres and W. K. Wootters in 1993. Since then, quantum teleportation has been realized in various physical systems. Presently, the record distance for quantum teleportation is 143 km (89 mi) with photons, and 21 m with material systems. In August 2013, the achievement of "fully deterministic" quantum teleportation, using a hybrid technique, was reported. On 29 May 2014, scientists announced a reliable way of transferring data by quantum teleportation. Quantum teleportation of data had been done before but with highly unreliable methods. [8]

Quantum Computing

A team of electrical engineers at UNSW Australia has observed the unique quantum behavior of a pair of spins in silicon and designed a new method to use them for "2-bit" quantum logic operations.

These milestones bring researchers a step closer to building a quantum computer, which promises dramatic data processing improvements.

Quantum bits, or qubits, are the building blocks of quantum computers. While many ways to create a qubits exist, the Australian team has focused on the use of single atoms of phosphorus, embedded inside a silicon chip similar to those used in normal computers.

The first author on the experimental work, PhD student Juan Pablo Dehollain, recalls the first time he realized what he was looking at.

"We clearly saw these two distinct quantum states, but they behaved very differently from what we were used to with a single atom. We had a real 'Eureka!' moment when we realized what was happening – we were seeing in real time the `entangled' quantum states of a pair of atoms." [5]

Quantum Entanglement

Measurements of physical properties such as position, momentum, spin, polarization, etc. performed on entangled particles are found to be appropriately correlated. For example, if a pair of particles is generated in such a way that their total spin is known to be zero, and one particle is found to have clockwise spin on a certain axis, then the spin of the other particle, measured on the same axis, will be found to be counterclockwise. Because of the nature of quantum measurement, however, this behavior gives rise to effects that can appear paradoxical: any measurement of a property of a particle can be seen as acting on that particle (e.g. by collapsing a number of superimposed states); and in the case of entangled particles, such action must be on the entangled system as a whole. It thus appears that one particle of an entangled pair "knows" what measurement has been performed on the other, and with what outcome, even though there is no known means for such information to be communicated between the particles, which at the time of measurement may be separated by arbitrarily large distances. [4]

The Bridge

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. [1]

Accelerating charges

The moving charges are self maintain the electromagnetic field locally, causing their movement and this is the result of their acceleration under the force of this field. In the classical physics the charges will distributed along the electric current so that the electric potential lowering along the current, by linearly increasing the way they take every next time period because this accelerated motion.
The same thing happens on the atomic scale giving a dp impulse difference and a dx way difference between the different part of the not point like particles.

Relativistic effect

Another bridge between the classical and quantum mechanics in the realm of relativity is that the charge distribution is lowering in the reference frame of the accelerating charges linearly: ds/dt = at (time coordinate), but in the reference frame of the current it is parabolic: $s = a/2\ t^2$ (geometric coordinate).

Heisenberg Uncertainty Relation

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 and proton are not point like particles, but has a real charge distribution.

Wave – Particle Duality

The accelerating electrons explains the wave – particle duality of the electrons and photons, since the elementary charges are distributed on delta x position with delta p impulse and creating a wave packet of the electron. The photon gives the electromagnetic particle of the mediating force of the electrons electromagnetic field with the same distribution of wavelengths.

Atomic model

The constantly accelerating electron in the Hydrogen atom is moving on the equipotential line of the proton and it's kinetic and potential energy will be constant. Its energy will change only when it is changing its way to another equipotential line with another value of potential energy or getting free with enough kinetic energy. This means that the Rutherford-Bohr atomic model is right and only that changing acceleration of the electric charge causes radiation, not the steady acceleration. The steady acceleration of the charges only creates a centric parabolic steady electric field around the charge, the magnetic field. This gives the magnetic moment of the atoms, summing up the proton and electron magnetic moments caused by their circular motions and spins.

The Relativistic Bridge

Commonly accepted idea that the relativistic effect on the particle physics it is the fermions' spin - another unresolved problem in the classical concepts. If the electric charges can move only with accelerated motions in the self maintaining electromagnetic field, once upon a time they would reach the velocity of the electromagnetic field. The resolution of this problem is the spinning particle, constantly accelerating and not reaching the velocity of light because the acceleration is radial. One origin of the Quantum Physics is the Planck Distribution Law of the electromagnetic oscillators, giving equal intensity for 2 different wavelengths on any temperature. Any of these two wavelengths will give equal intensity diffraction patterns, building different asymmetric constructions, for example proton - electron structures (atoms), molecules, etc. Since the particles are centers of diffraction patterns they also have particle – wave duality as the electromagnetic waves have. [2]

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. The Electroweak Interaction shows that the Weak Interaction is basically electromagnetic in nature. The arrow of time shows the entropy grows by changing the temperature dependent diffraction patterns of the electromagnetic oscillators.

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.

Fermions and Bosons

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

Van Der Waals force

Named after the Dutch scientist Johannes Diderik van der Waals – who first proposed it in 1873 to explain the behaviour of gases – it is a very weak force that only becomes relevant when atoms and molecules are very close together. Fluctuations in the electronic cloud of an atom mean that it will have an instantaneous dipole moment. This can induce a dipole moment in a nearby atom, the result being an attractive dipole–dipole interaction.

Electromagnetic inertia and mass

Electromagnetic Induction

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as an electromagnetic inertia, causing an electromagnetic mass. [1]

Relativistic change of mass

The increasing mass of the electric charges the result of the increasing inductive electric force acting against the accelerating force. The decreasing mass of the decreasing acceleration is the result of the inductive electric force acting against the decreasing force. This is the relativistic mass change explanation, especially importantly explaining the mass reduction in case of velocity decrease.

The frequency dependence of mass

Since $E = hv$ and $E = mc^2$, $m = hv /c^2$ that is the m depends only on the v frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the m_o inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

Electron – Proton mass rate

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! Also since the particles are diffraction patterns they have some closeness to each other – can be seen as a gravitational force. [2]

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.

Gravity from the point of view of quantum physics

The Gravitational force

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 Mp=1840 Me. 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.

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 Higgs boson

By March 2013, the particle had been proven to behave, interact and decay in many of the expected ways predicted by the Standard Model, and was also tentatively confirmed to have + parity and zero spin, two fundamental criteria of a Higgs boson, making it also the first known scalar particle to be discovered in nature, although a number of other properties were not fully proven and some partial results do not yet precisely match those expected; in some cases data is also still awaited or being analyzed.

Since the Higgs boson is necessary to the W and Z bosons, the dipole change of the Weak interaction and the change in the magnetic effect caused gravitation must be conducted. The Wien law is also important to explain the Weak interaction, since it describes the T_{max} change and the diffraction patterns change. [2]

Higgs mechanism and Quantum Gravity

The magnetic induction creates a negative electric field, causing an electromagnetic inertia. Probably it is the mysterious Higgs field giving mass to the charged particles? We can think about the photon as an electron-positron pair, they have mass. The neutral particles are built from negative and positive charges, for example the neutron, decaying to proton and electron. The wave – particle duality makes sure that the particles are oscillating and creating magnetic induction as an inertial mass, explaining also the relativistic mass change. Higher frequency creates stronger magnetic induction, smaller frequency results lesser magnetic induction. It seems to me that the magnetic induction is the secret of the Higgs field.

In particle physics, the Higgs mechanism is a kind of mass generation mechanism, a process that gives mass to elementary particles. According to this theory, particles gain mass by interacting with the Higgs field that permeates all space. More precisely, the Higgs mechanism endows gauge bosons in a gauge theory with mass through absorption of Nambu–Goldstone bosons arising in spontaneous symmetry breaking.

The simplest implementation of the mechanism adds an extra Higgs field to the gauge theory. The spontaneous symmetry breaking of the underlying local symmetry triggers conversion of components of this Higgs field to Goldstone bosons which interact with (at least some of) the other fields in the theory, so as to produce mass terms for (at least some of) the gauge bosons. This mechanism may also leave behind elementary scalar (spin-0) particles, known as Higgs bosons.

In the Standard Model, the phrase "Higgs mechanism" refers specifically to the generation of masses for the $W^{\pm}$, and Z weak gauge bosons through electroweak symmetry breaking. The Large Hadron Collider at CERN announced results consistent with the Higgs particle on July 4, 2012 but stressed that further testing is needed to confirm the Standard Model.

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 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]

Conclusions

The method developed by the researchers involves transferring a photonic qubit to an atomic qubit trapped inside an optical cavity. The photon-atom quantum information transfer is initiated via a quantum "logic-gate" operation, performed by reflecting the photon from the atom-cavity system, which creates an entangled atom-photon state. [9]

In August 2013, the achievement of "fully deterministic" quantum teleportation, using a hybrid technique, was reported. On 29 May 2014, scientists announced a reliable way of transferring data by quantum teleportation. Quantum teleportation of data had been done before but with highly unreliable methods. [8]

One of the most important conclusions is that the electric charges are moving in an accelerated way and even if their velocity is constant, they have an intrinsic acceleration anyway, the so called spin, since they need at least an intrinsic acceleration to make possible they movement .

The accelerated charges self-maintaining potential shows the locality of the relativity, working on the quantum level also. [1]

The bridge between the classical and quantum theory is based on this intrinsic acceleration of the spin, explaining also the Heisenberg Uncertainty Principle. The particle – wave duality of the electric charges and the photon makes certain that they are both sides of the same thing.

The Secret of Quantum Entanglement that the particles are diffraction patterns of the electromagnetic waves and this way their quantum states every time is the result of the quantum state of the intermediate electromagnetic waves. [2]

The key breakthrough to arrive at this new idea to build qubits was to exploit the ability to control the nuclear spin of each atom. With that insight, the team has now conceived a unique way to use the nuclei as facilitators for the quantum logic operation between the electrons. [5]

Basing the gravitational force on the accelerating Universe caused magnetic force and the Planck Distribution Law of the electromagnetic waves caused diffraction gives us the basis to build a Unified Theory of the physical interactions also.

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