Sound in Bose-Einstein Condensates

There are two sound velocities in a Bose-Einstein condensate. In addition to the normal sound propagation there is second sound, which is a quantum phenomenon. [22]

Quantum sensors can reach sensitivities that are impossible according to the laws of conventional physics that govern everyday life. [21]

An international team of physicists at ETH Zurich, Aalto University, the Moscow Institute of Physics and Technology, and the Landau Institute for Theoretical Physics in Moscow has demonstrated that algorithms and hardware developed originally in the context of quantum computation can be harnessed for quantum-enhanced sensing of magnetic fields. [20]

Scientists at Forschungszentrum Jülich have now discovered another class of particle-like magnetic object that could take the development of data storage devices a significant step forward. [19]

A team of researchers with members from IBM Research-Zurich and RWTH Aachen University has announced the development of a new PCM (phase change memory) design that offers miniaturized memory cell volume down to three nanometers. [18]

Monatomic glassy antimony might be used as a new type of single-element phase change memory. [17]

Physicists have designed a 3-D quantum memory that addresses the tradeoff between achieving long storage times and fast readout times, while at the same time maintaining a compact form. [16]

Quantum memories are devices that can store quantum information for a later time, which are usually implemented by storing and re-emitting photons with certain quantum states. [15]

The researchers engineered diamond strings that can be tuned to quiet a qubit's environment and improve memory from tens to several hundred nanoseconds, enough time to do many operations on a quantum chip. [14]

Intel has announced the design and fabrication of a 49-qubit superconducting quantum-processor chip at the Consumer Electronics Show in Las Vegas.

To improve our understanding of the so-called quantum properties of materials, scientists at the TU Delft investigated thin slices of $SrIrO_3$, a material that belongs to the family of complex oxides. [12]

New research carried out by CQT researchers suggest that standard protocols that measure the dimensions of quantum systems may return incorrect numbers. [11]

Is entanglement really necessary for describing the physical world, or is it possible to have some post-quantum theory without entanglement? [10]

A trio of scientists who defied Einstein by proving the nonlocal nature of quantum entanglement will be honoured with the John Stewart Bell Prize from the University of Toronto (U of T). [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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Author: George Rajna

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.

A new path to understanding second sound in Bose-Einstein condensates

There are two sound velocities in a Bose-Einstein condensate. In addition to the normal sound propagation there is second sound, which is a quantum phenomenon. Scientists in Ludwig Mathey's group from the University of Hamburg have put forth a new theory for this phenomenon.

When you jump into a lake and hold your head under water, everything sounds different. Apart from the different physiological response of our ears in air and water, this derives from the different sound propagation in water compared to air. Sound travels faster in water, checking in at 1493 m/s, on a comfortable summer day of 25°C. Other liquids have their own sound velocity, like alcohol with 1144 m/s, and helium, if you go to a chilling -269°C for its liquefied state, with 180 m/s.

These liquids are referred to as classical liquids, examples for one of the primary states of matter. But if we cool down that helium a few degrees more, something dramatic happens, it turns into a quantum liquid. This macroscopic display of quantum mechanics is a superfluid, a liquid that flows without friction.

So what do you hear if you make the unfortunate decision to stick your head into this liquid? Surprisingly, you will hear the same sound twice. In addition to the normal sound of a liquid there is the phenomenon of second sound that derives from the quantum nature of this liquid. If someone says something to you while immersed in superfluid helium, you will hear it as first sound first, and then get a second chance to listen when it arrives as second sound, albeit strongly muted. For superfluid helium, second sound is quite a bit slower than first sound, with 25 m/s vs. 250 m/s, between 1 and 2 Kelvin.

While the conventional theory of second sound has been successful for superfluid helium, the rise of Bose-Einstein condensates of ultracold atoms has posed new challenges. A team of scientists led by Ludwig Mathey from the University of Hamburg have put forth a new theory that captures second sound in these quantum liquids, recently published in *Physical Review A*.

"For superfluid helium, second sound is slower than first sound," explains co-author Vijay Singh, "but we were amazed to find that this is not necessarily true, that the second pulse can be faster." A new theoretical approach was needed to capture this. Modern problems require modern solutions, as they say.

"We generalized the Feynman path integral to expand the theory of superfluids," describes lead author Ilias Seifie the conceptual advance. While the path integral, brilliantly conceived by Richard Feynman, formulates quantum mechanics as a sum over trajectories, these trajectories themselves are classical. "We modified what these trajectories look like' continues Seifie, "in our path integral they contain information about quantum fluctuations." Imagine a pool noodle that stretches from A to B as a poor man's visualization of a trajectory that enters the Feynman path integral. The cross-section of the noodle is more or less round with a constant diameter along its length. But in the new path integral, the shape of the cross section can vary, it can take elliptical shapes, imagine squeezing the pool noodle together. Fittingly, physicists refer to these quantum mechanical states as squeezed states.

"This approach is widely applicable," explains Ludwig Mathey, "it can be applied to any method that is based on path integrals." Indeed, many phenomena at the interface of quantum and classical physics can be imagined to be better understood with this approach. One might just squeeze a bit more insight out of nature with this new framework. [22]

Redefining the limits of measurement accuracy

For centuries, humans have been expanding their understanding of the world through more and more precise measurement of light and matter. Today, quantum sensors achieve extremely accurate results. An example of this is the development of atomic clocks, which are expected to neither gain nor lose more than a second in thirty billion years. Gravitational waves were detected via quantum sensors as well, in this case by using optical interferometers.

Quantum sensors can reach sensitivities that are impossible according to the laws of conventional physics that govern everyday life. Those levels of sensitivity can only be reached if one enters the world of quantum mechanics with its fascinating properties—such as the phenomenon of superposition, where objects can be in two places at once and where an atom can have two different energy levels at the same time.

Both generating and controlling such non-classical states is extremely complex. Due to the high level of sensitivity required, these measurements are prone to external interference. Furthermore, non-classical states must be adapted to a specific measurement parameter. "Unfortunately, this often results in increased inaccuracy regarding other relevant measurement parameters", says Fabian Wolf, describing the challenge. This concept is closely linked to Heisenberg's uncertainty principle. Wolf is part of a team of researchers from Leibniz University Hannover, Physikalisch-Technische Bundesanstalt in Braunschweig, and the National Institute of Optics in Florence. The team introduced a method based on a non-classical state adapted to two measurement parameters at once.

The experiment can be visualised as the quantum mechanical version of a simple pendulum. In this case, the adapted measurement parameters are the pendulum's maximum displacement (amplitude) and the number of oscillations per second (frequency). The pendulum comprises a single magnesium ion embedded into an "ion trap." Via laser light interactions, researchers were able to cool the magnesium ion to the ground state of a quantum mechanical system, the coldest achievable state. From there, they generated a "Fock state" of the motion and oscillated the single atom pendulum using an external force. This allowed them to measure amplitude and frequency with a sensitivity unmatched by a conventional pendulum. In contrast to previous experiments, this was the case for both measurement parameters without having to adjust the non-classical state.

Using this new approach, the team reduced the measurement time by half while the resolution remained constant or doubled the resolution with a constant measurement time. High resolution is particularly important for spectroscopy techniques based on changing the state of motion. In this particular case, researchers intend to analyse individual molecular ions via laser irradiation in order to stimulate molecular movement. The new procedure will enable them to analyse the state of the molecule before it is disrupted by too intense laser irradiation. "For example, precision measurements of molecules could reveal interactions between conventional and dark matter, which would be a great contribution to solving one of the biggest mysteries in contemporary physics", says Fabian Wolf. The measurement concept, which researchers demonstrated for the first time, could also improve the resolution in optical interferometers such as gravitational wave detectors—therefore providing more in-depth insights into the dawn of the universe. [21]

A refined magnetic sense

An international team of physicists at ETH Zurich, Aalto University, the Moscow Institute of Physics and Technology, and the Landau Institute for Theoretical Physics in Moscow has demonstrated that algorithms and hardware developed originally in the context of quantum computation can be harnessed for quantum-enhanced sensing of magnetic fields.

The field of quantum science and technology experiences an ever-intensifying flurry of activity. The headlines are currently dominated by reports on progress towards building quantum computers that outperform their classical counterparts at specific computational tasks. A key challenge in that quest is to increase the quality and number of basic building blocks— known as quantum bits, or qubits— that can be connected to perform collectively quantum computations. The benchmark where a 'quantum advantage' is expected to emerge is at 50 or so qubits, and that goal is coming into sight. Pursuing a different route, a team including ETH physicists Andrey Lebedev and Gianni Blatter, together with colleagues in Finland and Russia, highlight another branch of technology where quantum devices promise unique benefits, and that with considerably more modest hardware resources. Writing in the journal *npj Quantum Information*, the team presents experiments in which they used a single qubit to measure magnetic fields with high sensitivity, employing 'quantum trickery' to push the limits.

In their work, the team used a qubit based on a superconducting circuit. The so-called transmon qubit is currently one of the leading candidates for a building block of large-scale quantum computers, as it offers flexibility for engineering the circuits in ways that suit the problem at hand. Researchers at Aalto University (Finland) have now built a transmon qubit in a configuration that makes it particularly suitable for sensing magnetic fields. In essence, they constructed an artificial atom with an intrinsic magnetic moment that is around 100,000 times larger than that of natural atoms or ions. The coupling of that large moment to an external magnetic field then makes it possible to measure the strength of the field accurately.

In addition to providing a strong coupling to a magnetic field, the transmon qubit has a defining property of a quantum system on offer: coherent superpositions of quantum states. In a qubit-based magnetometer, the coherence between two states oscillates at a frequency proportional to the magnetic field penetrating the device. And the higher the accuracy with which the frequency— or the rate at which the phase of the wavefunction changes— can be measured, the higher the sensitivity of the sensor.

To maximize the measurement accuracy, the team, guided by theoretical work performed by Lebedev and Blatter at ETH Zurich and co-workers at the Moscow Institute of Physics and Technology (MITP) and the Landau Institute for Theoretical Physics in Moscow, implemented two dedicated phase-estimation schemes that explicitly exploit the coherent nature of the qubit dynamics. Their strategy is to perform the measurements in an adaptive manner, changing the sampling parameters depending on the outcome of antecedent measurements. Such "Bayesian inference' enabled the team to reach in their experiments a sensitivity that is some six times higher than what can be achieved with classical phase estimation. And whereas there is still plenty of room for refinement, that 'quantum boost' was already sufficient to beat the shot noise, which limits the precision of any standard, classical measurement.

The phase-estimation algorithms used in the transmon experiments are suitably adapted versions of schemes that have been developed for use in quantum computations. Similarly, the design of the hardware used in these experiments draws on experience in building qubits for quantum computers. This combination of harnessing quantum hardware and quantum algorithms in the context of quantum sensing provides an appealing route towards novel devices that, ultimately, promise to push the sensitivity of single- or few-qubit magnetometers towards and beyond the limits of current magnetic-field sensors. [20]

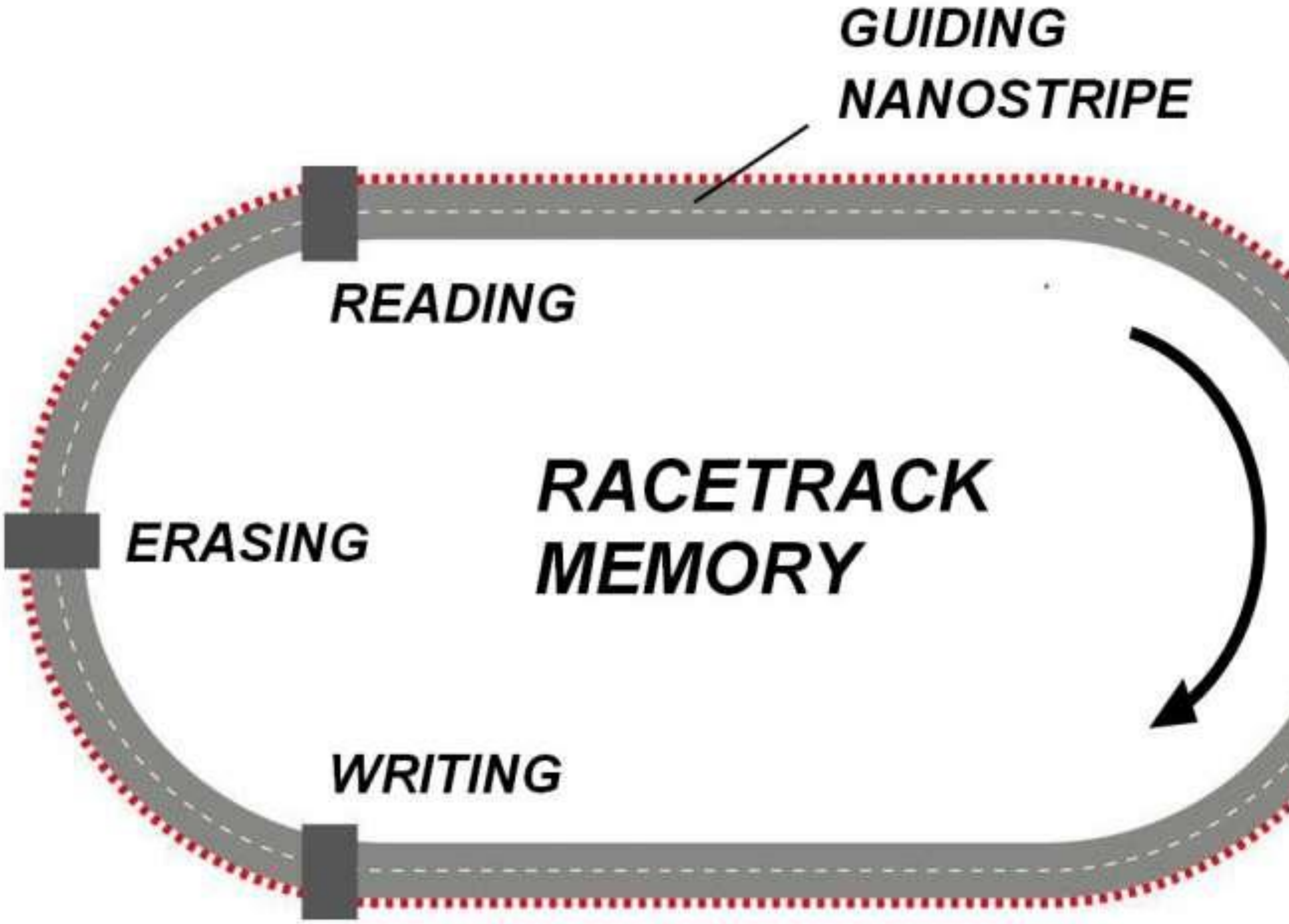
Researchers observe unique chiral magnetic phenomenon

Tiny magnetic vortex structures, so-called skyrmions, have been researched intensively for some time for future energy-efficient space-saving data storage devices. Scientists at Forschungszentrum Jülich have now discovered another class of particle-like magnetic object that could take the development of data storage devices a significant step forward. The newly discovered magnetic particles make it possible to encode digital data directly with two different types of magnetic objects, namely with skyrmions and magnetic bobbers—if skyrmions are used to encode the number one, then the new structures could be used to encode the number zero.

These objects, which are referred to as "chiral magnetic bobbers," are three-dimensional magnetic structures that appear near the surfaces of certain alloys.

"For a long time, the unique object for research in the field of chiral magnets was the magnetic skyrmion. We now provide a new object for investigation by researchers—a chiral bobber—which is characterized by a number of unique properties," says Dr. Nikolai Kiselev from Jülich's Peter Grünberg Institute (PGI-1). Three years ago, together with the institute's Director Prof. Stefan Blügel and other collaborators, they predicted the existence of this new class of magnetic structures theoretically. Now, researchers from the Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons (Director Prof. Rafal E. Dunin-Borkowski and his colleagues) have demonstrated the existence of chiral bobbers in a real material experimentally.

The stability of magnetic structures such as skyrmions is related to a property of the material known as chirality. Just as a right hand cannot be converted into a left hand for reasons of symmetry, right-handed and left-handed magnetic structures cannot be converted into one another. Furthermore, both skyrmions and the newly-discovered chiral bobbers are very small, with diameters of typically only a few tens of nanometers. Therefore, they can in principle be used to pack data very densely on a memory chip. However, their small size makes their observation highly challenging. "The visualization of magnetic texture on such a small scale requires special state-of-the-art techniques that are accessible in only a few laboratories worldwide," explains Rafal Dunin-Borkowski.



The concept of racetrack memory: magnetic objects move from writing to reading elements. Credit: Forschungszentrum Jülich

There is another important reason why magnetic solitons (another name for particle-like objects in nonlinear physics) such as skyrmions and chiral bobbers are so promising for applications. In contrast to data bits in hard disk drives, skyrmions are movable objects. Their motion along a guiding track in a chip can be induced by a very weak pulse of electrical current. This property provides new opportunities for the development of a completely new concept of magnetic solid-state memory—the so-called skyrmion racetrack memory. "The mobility of skyrmions allows data to move from write to read elements without the need for any movable mechanical parts such as read and write heads and spining hard disk itself," explains Nikolai Kiselev. This capability saves energy because components that move generally require more energy, occupy more space and tend to be sensitive to mechanical vibrations and shocks. A new solid state magnetic memory would be free of such disadvantages.

"Until now, it was assumed that digital data should somehow be represented as a sequence of skyrmions and empty spaces," says Stefan Blügel. The distance between successive skyrmions then encodes binary information. However, it must then be controlled or quantized, so that no information is lost through spontaneous drift of the skyrmions. Instead, the newly discovered three-dimensional magnetic particles offer opportunities to encode digital data directly as a sequence of skyrmions and magnetic bobbers, which can each flow freely without needing to maintain precise distances between successive data bit carriers.

Further research is required to develop practical applications. In the iron-germanium alloy studied by Nikolai Kiselev and his colleagues, the structures are only stable up to 200 Kelvin, which corresponds to -73.5 degrees Celsius. However, based on theoretical considerations, it is predicted that magnetic bobbers may also occur in other chiral magnets and, like some recently discovered species of skyrmions, may also exist at room temperature. [19]

New design of PCM offers miniaturized memory cell volume down to 3nm

A team of researchers with members from IBM Research-Zurich and RWTH Aachen University has announced the development of a new PCM (phase change memory) design that offers miniaturized memory cell volume down to three nanometers. In their paper published in the journal *Nature Materials*, the group describes their new monatomic PCM and its advantages. Wei Zhang and Evan Ma with Xi'an Jiaotong University and Johns Hopkins University respectively offer a News & Views piece on the work done by the team in the same journal issue.

The need to store more data has become a pressing issue, Zhang and Ma note—global need doubles every year and is expected to grow to 44 zettabytes by 2020 and to 160 zettabytes by 2025. The problem is that current technology will not be able to handle that kind of growth because memory cells need to be smaller than are possible now—otherwise, storage will become unwieldy and much more expensive. For that reason, computer scientists have continued to look for new types of technology that store more in less space. One such technology involves using PCMs.

PCMs are a type of non-volatile RAM which exploit the unique properties of chalcogenide glass. They tend to be created using a mix of alloys doped to produce desired effects. They can be used to hold digital data by exploiting the resistance between an ordered crystalline phase and a disordered amorphous phase, allowing for recording, holding and erasing data without the need for electricity. But until this new effort, it has been problematic scaling them down without causing deterioration in useful properties.

To overcome issues of deterioration, the researchers found a single element, antimony, that could be used rather than a host of alloys. Doing so removed the need for partitioning, which typically leads to degradation of performance over millions of cycles, as cells are made smaller. Using the single element, the team found they were able to use films just three to 10 nanometers thick. They also overcame cooling issues, reaching a rate of nearly 10^{10} Kelvin per second.

The researchers acknowledge that some issues have yet to be resolved, such as the short lifetime of the amorphous state, but suggest what they have found so far looks very promising. [18]

Glassy antimony makes monatomic phase change memory

Monatomic glassy antimony might be used as a new type of single-element phase change memory. This is the new finding from researchers at IBM Research-Zurich and RWTH Aachen University who say that their approach avoids the problem of local compositional variations in conventional multi-element PCMs. This problem becomes ever more important as devices get smaller.

New-generation non-volatile memory

The worldwide volume of digital information is doubling every two years and could reach 160 zettabytes (10^9terabytes) by 2025 according to the latest whitepaper from the International Data Corporation (IDC). Phase change memories are one of the new types of non-volatile memory being studied to meet this demand. These memories are based on a material's ability to switch between two "0" and "1" states: a crystalline state with high electrical conductivity and a meta-stable amorphous state with low electrical conductivity. They are switched using electrical pulses that heat up the material and drive the transitions. The energy of the electrical pulses is lower when there is less material to heat up.

Conventional PCMs are usually made from a complex mix of alloys doped with additional chemical elements to tune their physical properties. While such materials can be used to make chips with good data storage densities, these could be increased further by scaling down the cell size of memory units. There is a problem in that the smaller the device, the more sensitive it becomes to local compositional variations in the alloy, which deteriorates the cell's properties.

"Our work shows that we can solve this problem by making the PCM from just one simple element instead of these complex doped alloys," explains Martin Salinga, lead author of this study. "Antimony (Sb) is semi-metallic in its crystalline phase and semiconducting as an amorphous thin film and shows a large contrast in resistivity between these two states. It can also crystallize very easily and quickly. This makes it a good choice for a PCM in a highly-confined structure, which usually slows down the crystalline kinetics."

Rapid melt-quenching in a nanoconfined volume

The researchers, reporting their work in *Nature Materials* 10.1038/s41563-018-0110-9, made pure Sb films that are between 3 and 10 nm thick and confined inside thermally and electrically insulating SiO_2layers that are 40-200-nm thick. They were able to electrically switch between the amorphous and crystalline states in these films in just 50 ns.

Until now, it had been difficult to make amorphous Sb because the element rapidly crystallizes at room temperature. Salinga and colleagues have now managed to do this by rapidly cooling (or quenching) the material from the melt at a rate as high as 10^{10} kelvin per second in a nanoconfined volume. The result: amorphous Sb that is stable for nearly 51 hours at 20°C.

Immediate applications

“The first applications that could benefit from a ‘monatomic PCM’ might be in the area of ‘in-memory’ computing, ‘memory-type storage class memory’ or ‘brain-inspired computing’”, IBM scientist and study co-author, Abu Sebastian tells *Physics World*. “These devices could be operated with 10-ns-long electrical pulses. We will likely be able to scale these devices down to ultra-small dimensions that will consume very little energy. Their monoatomic nature might also make them more robust to repeated switching cycles.”

It is not all plain sailing though: the amorphous state of Sb only lasts for around 100 seconds at 60-70°C, which is the typical operating temperature inside electronic devices, so the researchers say that this will have to be improved. “This may be achieved, for instance, by further reducing the Sb film thickness, confining Sb in all three dimensions, and designing better confinement materials,” comment Wei Zhang and Evan Ma at Xian Jiaotong University in China and Johns Hopkins University in the US in a related *Nature news & views* article. “The voltage pulse (currently 50 ns) required for amorphization (also) needs to be shortened to become competitive with DRAMs and SRAMs.

“What has been achieved by Salinga and colleagues is nevertheless unprecedented and eye-opening, in terms of the perspective that monatomic PCMs are indeed feasible, and that an elemental glass, usually considered impractical due to its poor glass-forming ability, may be rendered useful in memory devices,” they add. [17]

Compact 3-D quantum memory addresses long-standing tradeoff

Physicists have designed a 3-D quantum memory that addresses the tradeoff between achieving long storage times and fast readout times, while at the same time maintaining a compact form. The new memory has potential applications in quantum computing, quantum communication, and other technologies.

The physicists, Edwar Xie and coauthors at the Walther-Meissner-Institut, Technical University of Munich, and Nanosystems Initiative Munich (NIM), Germany, have published a paper on the new 3-D quantum memory in a recent issue of *Applied Physics Letters*.

"Since quantum information is very fragile, it needs to be processed fast or preserved in a suitable storage. These two requirements are typically conflicting," Xie told *Phys.org*. "The greatest significance of our work is that it shows how to build a device with fast access to stored quantum information, enabling fast processing, combined with a long storage time."

One of the greatest challenges facing any kind of quantum technology is enhancing the qubit lifetime, and when it comes to quantum memories, 3-D devices offer the longest coherence times, up to a few milliseconds. In these memories, qubits are stored in 3-D microwave waveguide cavities, whose slow decay times enable long qubit storage times. However, a tradeoff occurs in these devices, since fast readout times require the cavity decay to be fast.

Previously, researchers have addressed this tradeoff in various ways, such as by physically separating the storage and readout units. However, with separate units the devices become relatively large and bulky compared to 2-D memories, causing problems for scalability.

In order to simultaneously achieve long storage times, fast readout times, and a small footprint, in the new study the researchers made use of the multimode structure of 3-D cavities. In this approach, the researchers used antennas to couple a qubit to two distinct modes of a single 3-D microwave cavity, which is much more compact than using two entirely separate units. They engineered the cavity so that the memory mode has a quality factor that is 100 times larger than that of the readout mode, which leads to slow decay for the memory mode and fast decay for the readout mode.

As a result of this coupling, the researchers demonstrated that the qubit state can be read out on a timescale that is 100 times shorter than the storage time. Further, simulations showed that more accurate antenna positioning could extend the ratio between readout and storage time to 25,000. This value would significantly outperform the current highest reported ratio of 7300 for quantum memories with cylindrical 3-D cavities.

In the future, the researchers plan to make further improvements to the memory, such as scaling up by adding more qubits, coupling the qubit to higher cavity modes, and enabling the memory to store cat states (a superposition of two macroscopic states), which has potential applications in continuous variable quantum computing.

"One potential application of this compact 3-D quantum memory lies in the field of analog quantum simulation, where an engineered quantum circuit, such as a qubit, mimics an atom," Xie said. "Due to its compact size and relaxed requirements of cabling, our 3-D quantum memory platform is specifically suitable for building chains of artificial atoms for the simulation of molecules. Here, one cell of the chain consists of a single 3-D cavity with one qubit, a storage mode for intermediate information storage and a readout mode for fast information retrieval. The coupling to the neighboring cell can be achieved with another qubit." [16]

How can you tell if a quantum memory is really quantum?

Quantum memories are devices that can store quantum information for a later time, which are usually implemented by storing and re-emitting photons with certain quantum states. But often it's difficult to tell whether a memory is storing quantum or merely classical information. In a new paper, physicists have developed a new test to verify the quantum nature of quantum memories.

The researchers, Denis Rosset, Francesco Buscemi, and Yeong-Cherng Liang, have published a paper on the quantum memory test in a recent issue of *Physical Review X*.

"Quantum memories are indispensable components of long-distance quantum communication networks and potentially even in a full-scale quantum computer," Liang, a physicist at National Cheng Kung University in Taiwan, told *Phys.org*. "For these components to serve their purpose, it's essential that they can preserve, at least, the quantum entanglement between certain inputs to the memory and whatever other parts that did not enter the memory. Our work strikes the right balance in certifying any device that possesses this ability while making the minimal assumptions."

As the scientists explain, the quantum entanglement between the system stored in the memory and any remote systems not in the memory must be maintained for the entire storage time. If this entanglement is broken at any time, then the device no longer functions as a quantum memory but rather as an "entanglement-breaking channel" and as a result can transmit only classical information.

Although currently there are tests that can verify the quantum nature of a quantum memory, these tests have certain limitations. For one, they require the experimenter to trust that the measurement and state preparation devices used by the quantum memory are accurate. For this reason, these tests are called device-dependent protocols. However, a test that makes no assumptions cannot be "faithful," meaning it may overlook some genuine quantum memories. This is because these methods test for the violation of a Bell inequality as verification of entanglement, which is sufficient but not necessary, as some genuinely quantum channels do not violate Bell inequalities and so would not pass this test.

Although it would be ideal to design a test that is completely device-independent, the researchers explain that it is not possible to test a single memory in this manner, even in principle, due to the need to test the quantum memory at two different times. However, their new test is measurement-device-independent, meaning it still requires the state preparation device to be trusted, but no assumptions need to be made regarding the measurement device. The new test is also faithful, meaning it can correctly identify all quantum memories that function as non-entanglement-breaking quantum channels.

The new test uses a semiquantum framework that is very similar to that used in some tests of entanglement in quantum states, in which the entanglement refers to correlations in space, in contrast to the time-like entanglement in quantum memories. Conventional protocols for testing for space-like correlations often use two characters, Alice as the sender and Bob as the receiver of quantum states. But since quantum memories involve time-like correlations, the protocol needs only a single character, whom the researchers call Abby, to act as both the sender and receiver at different times. In the test proposed in the new study, by comparing the relative frequencies of the signals that Abby sends and receives, it is possible to estimate the time-like entanglement and therefore certify that a quantum memory can store quantum information.

The researchers showed that the new test is robust against noise and losses, and they expect that it should be possible to experimentally perform the test with current technology. The test would then provide a very useful tool for the future development of quantum memories.

"In the development of novel quantum technologies, it's crucial that there exists a reliable way to benchmark the relevant components and make sure that they function as expected," Liang said. "Our findings provide a way to certify one of the most important features of these components while making sure that we are not making more assumptions than necessary. With these tests, we hope that it simplifies the quality control procedures of quantum devices while not falling into the trap of making unjustifiable assumptions." [15]

Tunable diamond string may hold key to quantum memory

A quantum internet promises completely secure communication. But using quantum bits or qubits to carry information requires a radically new piece of hardware—a quantum memory. This atomic-scale device needs to store quantum information and convert it into light to transmit across the network.

A major challenge to this vision is that qubits are extremely sensitive to their environment, even the vibrations of nearby atoms can disrupt their ability to remember information. So far, researchers have relied on extremely low temperatures to quiet vibrations but, achieving those temperatures for large-scale quantum networks is prohibitively expensive.

Now, researchers at the Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS) and the University of Cambridge have developed a quantum memory solution that is as simple as tuning a guitar.

The researchers engineered diamond strings that can be tuned to quiet a qubit's environment and improve memory from tens to several hundred nanoseconds, enough time to do many operations on a quantum chip.

"Impurities in diamond have emerged as promising nodes for quantum networks," said Marko Loncar, the Tiantsai Lin Professor of Electrical Engineering at SEAS and senior author of the research. "However, they are not perfect. Some kinds of impurities are really good at retaining information but have a hard time communicating, while others are really good communicators but suffer from memory loss. In this work, we took the latter kind and improved the memory by ten times."

The research is published in *Nature Communications*.

Impurities in diamond, known as silicon-vacancy color centers, are powerful qubits. An electron trapped in the center acts as a memory bit and can emit single photons of red light, which would in turn act as long-distance information carriers of a quantum internet. But with the nearby atoms in the diamond crystal vibrating randomly, the electron in the center quickly forgets any quantum information it is asked to remember.

"Being an electron in a color center is like trying to study at a loud marketplace," said Srujan Meesala, a graduate student at SEAS and co-first author of the paper. "There is all this noise around you. If you want to remember anything, you need to either ask the crowds to stay quiet or find a way to focus over the noise. We did the latter."

To improve memory in a noisy environment, the researchers carved the diamond crystal housing the color center into a thin string, about one micron wide—a hundred times thinner than a strand of hair—and attached electrodes to either side. By applying a voltage, the diamond string stretches and increases the frequency of vibrations the electron is sensitive to, just like tightening a guitar string increases the frequency or pitch of the string.

"By creating tension in the string, we increase the energy scale of vibrations that the electron is sensitive to, meaning it can now only feel very high energy vibrations," said Meesala. "This process effectively turns the surrounding vibrations in the crystal to an irrelevant background hum, allowing the electron inside the vacancy to comfortably hold information for hundreds of nanoseconds, which can be a really long time on the quantum scale. A symphony of these tunable diamond strings could serve as the backbone of a future quantum internet."

Next, the researchers hope to extend the memory of the qubits to the millisecond, which would enable hundreds of thousands of operations and long-distance quantum communication. [14]

Intel unveils 49-qubit superconducting chip

Intel has announced the design and fabrication of a 49-qubit superconducting quantum-processor chip at the Consumer Electronics Show in Las Vegas. Speaking at the conference, Intel chief executive Brian Krzanich introduced “Tangle Lake”; a quantum-processor chip that operates at extremely low temperatures. The device takes its name from the Tangle Lakes, a frigid chain of lakes in Alaska, and is a nod to quantum entanglement.

Tangle Lake is designed to store and process quantum information in qubits that are superconducting circuits. Krzanich said that the chip is an important step towards developing quantum computers that could quickly solve mathematical problems involved in some of society’s most pressing issues – from drug development to climate forecasting.

Large-scale integration

He also announced progress in Intel’s research on spin qubits, which have qubits based on the spin states of single electrons. While superconducting chips tend to be relatively large, the spin-qubits could be miniaturized using well-established silicon-chip fabrication processes. This means that it may be possible to manufacture quantum processors containing large numbers of spin qubits. This large-scale integration would be could be more difficult for superconducting qubits.

However, there is some scepticism in the physics community regarding Intel’s silence about the performance and quality specifications of Tangle Lake and their spin qubit chips. Intel is also facing fierce competition. IBM has itself announced quantum computers with 20 and 50 superconducting qubits in recent months, and companies including Google and Rigetti are also securing footholds in the nascent market.

Commercial quest

“In the quest to deliver a commercially viable quantum computing system, it’s anyone’s game,” confesses Mike Mayberry, managing director at Intel Labs. “We expect it will be five to seven years before the industry gets to tackling engineering-scale problems, and it will likely require one million or more qubits to achieve commercial relevance.” [13]

Scientists explore quantum properties in the two-dimensional limit

As electronic components become smaller, understanding how materials behave at the nanoscale is crucial for the development of next-generation electronics. Unfortunately, it is very difficult to predict what happens when materials are only a few atomic layers thick. To improve our understanding of the so-called quantum properties of materials, scientists at the TU Delft investigated thin slices of $SrIrO_3$, a material that belongs to the family of complex oxides. Their findings have recently been published *Physical Review Letters*.

The researchers synthesized the material using pulsed laser deposition (PLD), a method for depositing single crystal films with atomic layer precision. "We studied crystals with thicknesses down to 2 atomic layers (0.8 nanometres)," said lead author Dirk Groenendijk, who is a Ph.D. candidate at TU Delft.

Electrons can normally move freely in the material, and $SrIrO_3$ shows metallic behaviour. However, the scientists found that at a thickness of 4 layers, there appears to be a turning point. Below this thickness, the electrons become localized and the material transitions to an insulating state. At the same time, the material orders magnetically and the effects of spin-orbit coupling are strongly enhanced. This last property is of interest for the development of new magnetic memory devices, because the spin of the electron can be used to store and transfer information.

The next generation of electronic devices will require further miniaturization of their components, and it will not be long before chip manufacturers go below 10 nanometres. "At this scale, you can count the number of atoms, and you enter the realm of quantum mechanics," says Groenendijk. For future devices, researchers are also looking for new materials with currently inaccessible functionalities. In this respect, complex oxides are promising candidates that display a wide variety of exotic phenomena. The research of Groenendijk and colleagues constitutes an important step towards the understanding of their quantum properties in the two-dimensional limit. [12]

Do Physicists Need to Change the Way They Measure Quantum States?

New research carried out by CQT researchers suggest that standard protocols that measure the dimensions of quantum systems may return incorrect numbers. For that reason, Cai Yu, Cong Wan and Valerio Scarani and Jean Bancal want to create a new concept of 'irreducible dimensions.' However, in doing so, physicists will need to re-evaluate how they'll measure the dimensions of quantum states moving forward.

The CQT researchers concentrate on Hilbert Space when conducting their research, which is a realm of potentially infinite dimensions that are inhabited by quantum systems. "The goal of our paper is to show there is a conceptual problem in how dimension witnesses are defined," confirms Valerio Scarani, CQT Principal Investigator.

For proper implementation of quantum communication and protocols, accurate measuring is needed, and that's where the Hilbert Space dimension comes in. This part of the quantum system will let you know exactly how much information can be stored in the system.

In completing their research, the team discovered that the measurement protocols designed to calculate the dimension of a state (the dimension witness) were unable to distinguish between a high-dimension state and a low one. One of the first to raise doubts about the way in which dimension witnesses worked was Post doctorate Jean-Daniel.

Valerio told everyone to stop and reset, and the team proceeded to rewrite their conclusions. While some of the team were doing this, Wan and Cai began working on a new theory involving dimension witnesses, leading to the publishing of their paper. [11]

Entanglement is an inevitable feature of reality

Is entanglement really necessary for describing the physical world, or is it possible to have some post-quantum theory without entanglement?

In a new study, physicists have mathematically proved that any theory that has a classical limit—meaning that it can describe our observations of the classical world by recovering classical theory under certain conditions—must contain entanglement. So despite the fact that entanglement goes against classical intuition, entanglement must be an inevitable feature of not only quantum theory but also any non-classical theory, even those that are yet to be developed.

The physicists, Jonathan G. Richens at Imperial College London and University College London, John H. Selby at Imperial College London and the University of Oxford, and Sabri W. Al-Safi at Nottingham Trent University, have published a paper establishing entanglement as a necessary feature of any non-classical theory in a recent issue of Physical Review Letters.

"Quantum theory has many strange features compared to classical theory," Richens told Phys.org. "Traditionally we study how the classical world emerges from the quantum, but we set out to reverse this reasoning to see how the classical world shapes the quantum. In doing so we show that one of its strangest features, entanglement, is totally unsurprising. This hints that much of the apparent strangeness of quantum theory is an inevitable consequence of going beyond classical theory, or perhaps even a consequence of our inability to leave classical theory behind."

Although the full proof is very detailed, the main idea behind it is simply that any theory that describes reality must behave like classical theory in some limit. This requirement seems pretty obvious, but as the physicists show, it imparts strong constraints on the structure of any nonclassical theory.

Quantum theory fulfills this requirement of having a classical limit through the process of decoherence. When a quantum system interacts with the outside environment, the system loses its quantum coherence and everything that makes it quantum. So the system becomes classical and behaves as expected by classical theory.

Here, the physicists show that any non-classical theory that recovers classical theory must contain entangled states. To prove this, they assume the opposite: that such a theory does not have entanglement. Then they show that, without entanglement, any theory that recovers classical theory must be classical theory itself—a contradiction of the original hypothesis that the theory in question is non-classical. This result implies that the assumption that such a theory does not have entanglement is false, which means that any theory of this kind must have entanglement.

This result may be just the beginning of many other related discoveries, since it opens up the possibility that other physical features of quantum theory can be reproduced simply by requiring that the theory has a classical limit. The physicists anticipate that features such as information causality, bit symmetry, and macroscopic locality may all be shown to arise from this single requirement. The results also provide a clearer idea of what any future non-classical, post-quantum theory must look like.

"My future goals would be to see if Bell non-locality can likewise be derived from the existence of a classical limit," Richens said. "It would be interesting if all theories superseding classical theory must violate local realism. I am also working to see if certain extensions of quantum theory (such as higher order interference) can be ruled out by the existence of a classical limit, or if this limit imparts useful constraints on these 'post-quantum theories.'" [10]

Bell Prize goes to scientists who proved 'spooky' quantum entanglement is real

A trio of scientists who defied Einstein by proving the nonlocal nature of quantum entanglement will be honoured with the John Stewart Bell Prize from the University of Toronto (U of T). The prize recognizes the most significant recent achievements in the world in quantum mechanics and is considered by many to be the top international award in the field.

The recipients each led separate experiments in 2015 that showed two particles so distant from one another that no signal could connect them even at the speed of light nevertheless possessed an invisible and instantaneous connection. They are:

Ronald Hanson, Delft University of Technology, Netherlands

Sae-Woo Nam of the National Institute of Standards & Technology, United States

Anton Zeilinger, University of Vienna, Austria

According to quantum entanglement, the world is a very weird place where quantum particles become correlated in pairs. These pairs predictably interact with each other regardless of how far apart they are: if you measure the properties of one member of the entangled pair you know the properties of the other. Einstein was not a believer: in the 1930s, he called it "spooky action at a distance."

"While many experiments have come close to proving quantum entanglement, the scientists we are honouring have closed previous loopholes," says Professor Aephraim Steinberg, a quantum physicist at the U of T's Centre for Quantum Information & Quantum Control (CQIQC) and one of the founders of the Bell Prize. Earlier tests, for example, were plagued by the difficulties of ensuring that no signal could make it from one detector to the other as well as the fact that so many photons were being lost in the test process.

"Collectively, they have removed all reasonable doubt about the nonlocal nature of quantum entanglement. In so doing they are also opening the door to exciting new technologies including super-secure communications and the ability to perform certain computations exponentially faster than any classical computer," says Steinberg.

Created by the CQIQC at U of T in 2005, the John Stewart Bell Prize for Research on Fundamental Issues in Quantum Mechanics and their Applications is judged by an international panel of experts and awarded every two years for achievements in the previous six years.

"Advancing understanding of quantum mechanics, along with its technological applications, is something that deserves to be celebrated and recognized around the world. We expect that, in some cases, the Bell Prize will prove to be a precursor to the Nobel Prize in Physics," says Daniel James, director of the CQIQC.

The prize will be awarded on Thursday, August 31 at 1:25 pm at the Fields Institute on the U of T campus. Recipients will give short talks after the ceremony. [9]

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]

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 $E = h\nu$ and $E = mc^2$, $m = h\nu /c^2$ that is the m depends only on the ν 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

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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