Hydrologic Simulation Models

Hydrologic models that simulate and predict water flow are used to estimate how natural systems respond to different scenarios such as changes in climate, land use, and soil management. [30]

Nanomaterials could provide the basis of many emerging technologies, including extremely tiny, flexible, and transparent electronics. [29]

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The lifespan of a liquid droplet which is transforming into vapour can now be predicted thanks to a theory developed at the University of Warwick. [27]

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A UCF physicist has discovered a new material that has the potential to become a building block in the new era of quantum materials, those that are composed of microscopically condensed matter and expected to change our development of technology. [25]

Researchers at the University of Geneva (UNIGE), Switzerland, in partnership with CNRS, France, have discovered a new material in which an element, ytterbium, can store and protect the fragile quantum information even while operating at high frequencies. [24]

Scientists at the University of Alberta in Edmonton, Canada have created the most dense, solid-state memory in history that could soon exceed the capabilities of current hard drives by 1,000 times. [23]

The team showed that the single-atom magnets can endure relatively high temperatures and strong external magnetic fields. The work could lead to the development of extremely high-density data storage devices. [22]

One of these are single-atom magnets: storage devices consisting of individual atoms stuck ("adsorbed") on a surface, each atom able to store a single bit of data that can be written and read using quantum mechanics. [21]

Physicists have experimentally demonstrated 18-qubit entanglement, which is the largest entangled state achieved so far with individual control of each qubit. [20]

University of Adelaide-led research has moved the world one step closer to reliable, high-performance quantum computing. [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.

Hydrologic simulation models that inform policy decisions are difficult to interpret

Hydrologic models that simulate and predict water flow are used to estimate how natural systems respond to different scenarios such as changes in climate, land use, and soil management. The

output from these models can inform policy and regulatory decisions regarding water and land management practices.

Numerical models have become increasingly easy to employ with advances in computer technology and software with graphical user interface (GUI). While these technologies make the models more accessible, problems can arise if they are used by inexperienced modelers, says Juan Sebastian Acero Triana, a doctoral student in the Department of Agricultural and Biological Engineering at the University of Illinois.

Acero Triana is lead author on a study that evaluates the accuracy of a commonly used numerical model in hydrology.

Findings from the research show that even when the model appears to be properly calibrated, its results can be difficult to interpret correctly. The study, published in the *Journal of Hydrology*, provides recommendations for how to fine-tune the process and obtain more precise results.

Model accuracy is important to ensure that policy decisions are based on realistic scenarios, says Maria Chu, a co-author of the study. Chu is an assistant professor of agricultural and biological engineering in the College of Agricultural, Consumer and Environmental Sciences and The Grainger College of Engineering at U of I.

"For example, you may want to estimate the impacts of future climate on the water availability over the next 100 years. If the model is not representing reality, you are going to draw the wrong conclusions. And wrong conclusions will lead to wrong policies, which can greatly affect communities that rely on the water supply," Chu says.

The study focuses on the Soil and Water Assessment model (SWAT), which simulates water circulation by incorporating data on land use, soil, topography, and climate. It is a popular model used to evaluate the impacts of climate and land management practices on water resources and contaminant movement.

The researchers conducted a case study at the Fort Cobb Reservoir Experimental Watershed (FCREW) in Oklahoma to assess the model's accuracy. FCREW serves as a test site for the United States Department of Agriculture-Agricultural Research Service (USDA-ARS) and the United States Geological Survey (USGS); thus, detailed data are already available on stream flow, reservoir, groundwater, and topography.

The study coupled the SWAT model with another model called MODFLOW, or the Modular Finite-difference Flow Model, which includes more detailed information on groundwater levels and fluxes.

"Our purpose was to determine if the SWAT model by itself can appropriately represent the hydrologic system," Acero Triana says. "We discovered that is not the case. It cannot really represent the entire hydrologic system."

In fact, the SWAT model yielded 12 iterations of water movement that all appeared to be acceptable. However, when combined with MODFLOW it became clear that only some of these

results properly accounted for groundwater flow. The researchers compared the 12 results from SWAT with 103 different groundwater iterations from MODFLOW in order to find a realistic representation of the water fluxes in the watershed.

Yielding several different results that all appear equally likely to be correct is called "equifinality." Careful calibration of the model can reduce equifinality, Acero Triana explains. Calibration must also be able to account for inherent limitations in the way the model is designed and how parameters are defined. In technical terms, it must account for model and constraint inadequacy.

However, inexperienced modelers may not fully understand the intricacies of calibration. And because of the inherent constraints of both SWAT and MODFLOW, using metrics from just one model may not provide accurate results.

The researchers recommend using a combination model called SWATmf, which integrates the SWAT and the MODFLOW processes.

"This paper presents a case study that provides general guidelines for how to use hydrological models," Acero Triana says. "We show that to really represent a hydrologic system you need two domain models. You need to represent both the surface and the sub-surface processes that are taking place."

The differences in results may be small, but over time the effect could be significant, he concludes.

The article, "Beyond model metrics: The perils of calibrating hydrologic models" is published in *Journal of Hydrology*. [30]

New research integrates borophene and graphene into 2-D heterostructures

Nanomaterials could provide the basis of many emerging technologies, including extremely tiny, flexible, and transparent electronics.

While many nanomaterials exhibit promising electronic properties, scientists and engineers are still working to best integrate these materials together to eventually create semiconductors and circuits with them.

Northwestern Engineering researchers have created two-dimensional (2-D) heterostructures from two of these materials, graphene and borophene, taking an important step toward creating intergrated circuits from these nanomaterials.

"If you were to crack open an integrated circuit inside a smartphone, you'd see many different materials integrated together," said Mark Hersam, Walter P. Murphy Professor of Materials Science and Engineering, who led the research. "However, we've reached the limits of many of those traditional materials. By integrating nanomaterials like borophene and graphene together, we are opening up new possibilities in nanoelectronics."

Supported by the Office for Naval Research and the National Science Foundation, the results were published October 11 in the journal *Science Advances*. In addition to Hersam, applied physics Ph.D. student Xiaolong Liu co-authored this work.

Creating a new kind of heterostructure

Any integrated circuit contains many materials that perform different functions, like conducting electricity or keeping components electrically isolated. But while transistors within circuits have become smaller and smaller—thanks to advances in materials and manufacturing—they are close to reaching the limit of how small they can get.

Ultrathin 2-D materials like graphene have the potential to bypass that problem, but integrating 2-D materials together is difficult. These materials are only one atom thick, so if the two materials' atoms do not line up perfectly, the integration is unlikely to be successful. Unfortunately, most 2-D materials do not match up at the atomic scale, presenting challenges for 2-D integrated circuits.

Borophene, the 2-D version of boron that Hersam and coworkers first synthesized in 2015, is polymorphic, meaning it can take on many different structures and adapt itself to its environment. That makes it an ideal candidate to combine with other 2-D materials, like graphene.

To test whether it was possible to integrate the two materials into a single heterostructure, Hersam's lab grew both graphene and borophene on the same substrate. They grew the graphene first, since it grows at a higher temperature, then deposited boron on the same substrate and let it grow in regions where there was no graphene. This process resulted in lateral interfaces where, because of borophene's accommodating nature, the two materials stitched together at the atomic scale.

Measuring electronic transitions

The lab characterized the 2-D heterostructure using a scanning tunneling microscope and found that the electronic transition across the interface was exceptionally abrupt—which means it could be ideal for creating tiny electronic devices.

"These results suggest that we can create ultrahigh density devices down the road," Hersam said. Ultimately, Hersam hopes to achieve increasingly complex 2-D structures that lead to novel electronic devices and circuits. He and his team are working on creating additional heterostructures with borophene, combining it with an increasing number of the hundreds of known 2-D materials.

"In the last 20 years, new materials have enabled miniaturization and correspondingly improved performance in transistor technology," he said. "Two-dimensional materials have the potential to make the next leap." [29]

Physicists look to navigational 'rhumb lines' to study polymer's unique spindle structure

From the intricate patterns of pollen grains to the logarithmic spirals of nautilus shells, biology is full of complex patterns, shapes, and geometries. Many of these intricate structures play important roles in biological function, but can be difficult to create in a lab without state-of-the-art equipment or expensive and energy-consuming processes and materials.

A new study describes how spheres can be transformed into twisted spindles thanks to insights from 16th century navigational tools. Researchers show how polymers can contract into spiral structures, known as loxodromes, that have complex patterning ten times smaller than the width of a human hair. Published in *Physical Review Letters*, the research was conducted by University of Pennsylvania graduate student Helen Ansell, postdoc Daeseok Kim, and professors Randall Kamien and Eleni Katifori in the School of Arts and Sciences, in collaboration with Teresa Lopez-Leon of the École Supérieure de Physique et de Chimie Industrielles de la Ville de Paris (ESPCI).

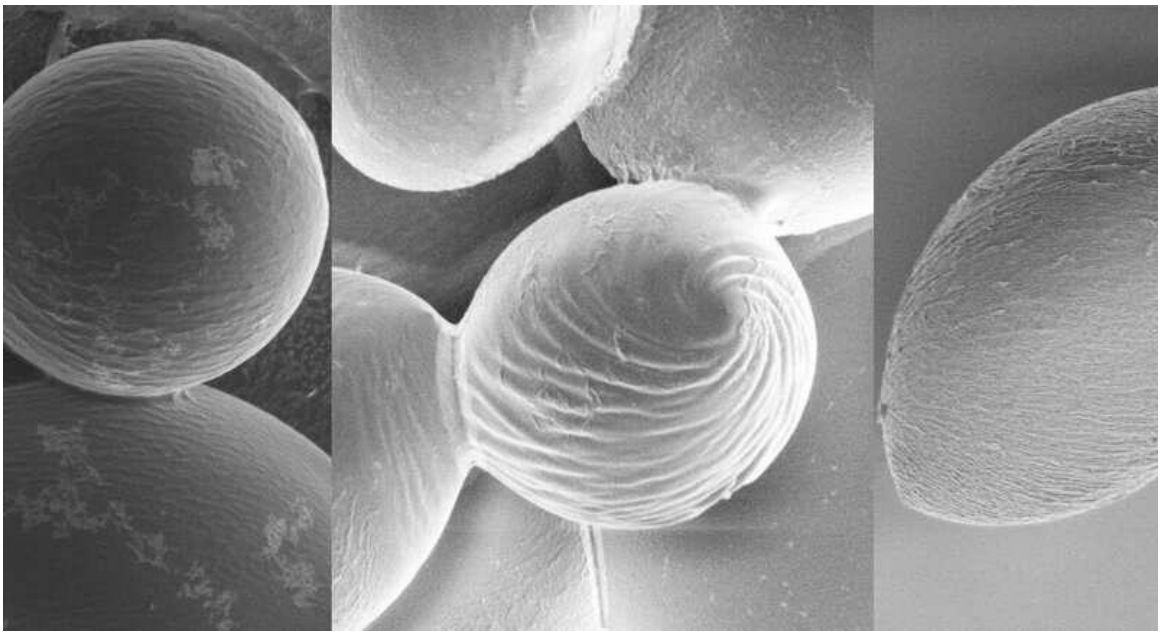
Kim, who worked on this project at ESPCI before coming to Penn, was inspired by other studies showing that a mixture of polymer and liquid crystal took on a new shape when placed in a different solvent. It was a change that was also reversible and reproducible, with little to no energy required to cause the change in shape.

To understand the interesting conformational changes that Kim had seen in the lab, he sought out theorists who could help make sense of how the polymer's geometry caused it to twist and contract. After seeing the microscopic images and data that was collected and analyzed by Kim, Ansell had an initial idea of what the spindle's structure might be: a loxodrome.

More commonly referred to as rhumb lines, a loxodrome is an arc that follows a constant angle as it cuts across a sphere. Sailors throughout the 16th-19th centuries used these lines to navigate, allowing them to set their compasses to a constant bearing so that their ship did not have to change its bearing.

"We tried to figure out if this was the case," Ansell says about investigating if her hypothesis was correct. "We think we found these loxodromes, so we had to go about comparing what does it look like versus the data."

Ansell then developed a mathematical model that describes how the spheres become elongated and twisted using the geometry of the loxodrome as a starting point. By comparing the results of her theory to the data generated by Kim, she was able to show that changing the solvent caused the polymers to shrink, which caused its shape to twist as the polymer chains along the sphere's lines of longitude became shorter.



Scanning electron microscope images showing polymers in a spherical configuration (far left); when a new solvent is added, the spheres twist and change into elongated twisted spindles (far right). At the top of the spindles (center panel) are one micron spirals. (Image: Daeseok Kim) Credit: Daeseok Kim

At the top of the spindles are one micron spirals, nearly one hundred times smaller than the width of a human hair. Creating manmade patterns that small usually requires costly methods and equipment, but this method of making self-assembled small-scale structures using course-scale starting materials is much simpler.

The polymer loxodrome is the latest finding that delves into the Kamien group's interests in the crossover between chemistry and geometry. Kamien says that many interactions in biology, like protein folding, immune responses, and even smell, is usually depicted as a chemical bond, but emphasizes that geometry also drives much of what happens in biology.

"Think about proteins," says Kamien, "You have these different amino acids, and they attract in different ways, but when you're all done, you have this giant glob, and there's this little pocket that grabs the residues, so you think of it geometrically. Helen's explanation is completely geometrical: It doesn't involve anything specific about how the binding works."

For Kim, this research is an exciting first step for studying unique structures in other biological systems. By designing new types of polymer particles and testing them out in different conditions, he hopes to learn more about how shape drives function, especially in systems that twist and contract. "We could study some biological matter in nature by mimicking a similar topological model," he says, "And we may solve or study some complex problem in nature."

Now, entirely coincidentally, Ansell's efforts have laid the groundwork for another unrelated project she had been stuck on for some time which also appears to have a loxodrome solution.

"They just appear," she says about the twisted spindle shape.

"As Pasteur said, luck favors the prepared mind," adds Kamien. "Now, we're primed to look for them." [28]

The lifespan of an evaporating liquid drop

The lifespan of a liquid droplet which is transforming into vapour can now be predicted thanks to a theory developed at the University of Warwick. The new understanding can now be exploited in a myriad of natural and industrial settings where the lifetime of liquid drops governs a process' behaviour and efficiency.

Water evaporating into vapour forms part of our daily existence, creating plumes emanating from a boiling kettle and bulging clouds as part of the earth's water cycle. Evaporating liquid drops are also commonly observed, e.g. as the morning dew disappears off a spider's web, and are critical for technologies such as fuel-injection combustion engines and cutting-edge evaporative cooling devices for next generation electronics.

Researchers from the Mathematics Institute and School of Engineering at the University of Warwick have had the paper "Lifetime of a Nanodroplet: Kinetic Effects & Regime Transitions," published in the journal *Physical Review Letters*, in which they explore the lifespan of a liquid droplet.

Current theories state that the droplet's diameter-squared decreases in proportion to time (classical law); however, this period only accounts for a small portion of the drop's evolution. As the diameter approaches the unobservable micro- and nano-scale, molecular dynamics have to be used as virtual experiments and these show a crossover to a new behaviour, with the diameter now reducing in proportion to time (nano-scale law).

Research at Warwick has shown that this behaviour occurs due to complex physics in the vapour flow, which can result in jumps in temperature across just a few molecules as large as 40 degrees! This behaviour is counter-intuitive to our daily experiences (on the macroscale), where we are used to temperatures changing relatively gradually, but must be accounted for to accurately predict the final stages of an evaporating drop's life.

Prof Duncan Lockerby from the School of Engineering at the University of Warwick comments:

"The main achievement here is the theory's ability to quickly predict the drop's lifetime and create a modelling framework that maintains accuracy from typical engineering scales down to cutting-edge nanoscale applications"

Dr. James Sprittles from the Mathematics Institute at the University of Warwick comments:

"It is fascinating that intuition based on everyday observations are a hindrance when attempting to understand nanoscale flows, so that, as in this research, one has to lean on theory to enlighten us." [27]

What doesn't crack them makes them stronger

What doesn't kill us makes us stronger, according to philosopher Friedrich Nietzsche. Who would have thought that a similar notion might apply to materials?

"The reason concrete is so strong is because it's so weak," says Professor Alex Hansen, head of PoreLab, a Centre of Excellence for outstanding research at the Norwegian University of Science and Technology (NTNU) and the University of Oslo (UiO).

Researchers at PoreLab work mostly with porous materials like concrete, and in their world, this sort of thing can happen. Among other things, the researchers consider what happens in materials subjected to stress, and some of their findings are a bit unexpected.

Why, for example, does concrete function in this way? Concrete looks compact, but it's actually full of tiny holes. These holes make the material stronger. Professor Hansen starts with the basics:

"When you get a crack in your car's windshield, you can stop that crack from spreading by drilling a hole in it," he says. An untreated crack has a high concentration of force at the tip of the crack. If you drill a hole at this point, the force instead spreads around the hole and lessens the pressure on the glass.

Something similar occurs in the porous concrete. If there's a crack in the concrete, the force gets distributed throughout the material due to all the holes. People have known about these force mechanisms at least since the Middle Ages. The builders of the Kristiansten fortress in Trondheim in the 17th century put the remains of dead animals into the material. As the animals rotted and emitted gases, they made the material porous and thus stronger.

But this doesn't explain why materials can become even stronger under strain. The idea flies in the face of intuition—shouldn't the material get weaker instead? What's going on?

Doctoral candidate Jonas Tøgersen Kjellstadli from NTNU's Department of Physics can explain the process. He has collaborated with Hansen, researcher Srutarshi Pradhan and Ph.D. candidate Eivind Bering—also from the same department—in studying the phenomenon. "The strong parts of the material surround the weak parts and protect them," says Kjellstadli.

A material like concrete isn't equally strong everywhere, though it may look like it. An apparently uniform material has weak and strong zones. These zones are randomly scattered throughout it.

In the computer models used by Kjellstadli, the strong zones are spread around in the material. They protect the weak zones when the fibres are subjected to stressors. This happens to such a strong degree that the material is stabilized and becomes less vulnerable to such stresses.

This effect only applies where the strong and weak zones are unevenly distributed throughout the material. And it only applies up to a certain threshold. The material is constantly being stressed to some maximum threshold or another, where the force of a stress can no longer be absorbed. Sooner or later, the material will then fail catastrophically and suddenly.

The researchers envision possible applications, as well. What if you could use this basic knowledge to predict when a material will fail? When does the stress finally get to be too much? "We use the same computer models as when we observe that materials are strengthened by the stress load," says Hansen.

To that, they add practical experiments, continuing until the stress load becomes too great for the material.

Hansen has been interested in this topic since 2000, when he heard about mines in South Africa that would suddenly collapse. Understanding these same principles could someday be used as an aid during tunnel construction, or to predict earthquakes. These ideas are still speculative, and their applications lie in the somewhat distant future. But the researchers' ambitions are high.

"We're working on coming up with a general model for when catastrophic failure sets in, says Hansen.

Whether this goal is even possible, they don't yet know—but this is exactly the kind of high-risk research PoreLab has been charged with carrying out. The potential gains are huge if they succeed.

"In our computer models, we're observing that the elastic energy of the material reaches a peak just before it fails," says PoreLab researcher Pradhan. He has been working specifically on predicting when a material will crack ever since he started studying under Professor Bikas K. Chakrabarti at the Saha Institute of Nuclear Physics in Kolkata, India in 2000. "We believe this has the potential to expand into real situations," Pradhan says.

Maybe their goal isn't impossible after all. [26]

Team discovers a first-of-its-kind material for the quantum age

A UCF physicist has discovered a new material that has the potential to become a building block in the new era of quantum materials, those that are composed of microscopically condensed matter and expected to change our development of technology.

Researchers are entering the Quantum Age, and instead of using silicon to advance technology they are finding new quantum materials, conductors that have the ability to use and store energy at the subatomic level.

Assistant Professor Madhab Neupane has spent his career learning about the quantum realm and looking for these new materials, which are expected to become the foundation of the technology to develop quantum computers and long-lasting memory devices. These new devices will increase computing power for big data and greatly reduce the amount of energy required to power electronics.

Big companies recognize the potential and they are investing in research. Microsoft has invested in its Station Q, a lab dedicated solely to studying the field of topological quantum computing. Google has teamed up with NASA on a Quantum AI Lab that studies how quantum computing and

artificial intelligence can mesh. Once the quantum phenomena are well understood and can be engineered, the new technologies are expected to change the world, much like electronics did at the end of the 20th century.

Neupane's discovery, published today in *Nature Communications* is a big step in making that reality happen.

"Our discovery takes us one step closer to the application of quantum materials and helps us gain a deeper understanding of the interactions between various quantum phases," Neupane said.

The material Neupane and his team discovered, Hf_2Te_2P—chemically composed of hafnium, tellurium and phosphorus—is the first material that has multiple quantum properties, meaning there is more than one electron pattern that develops within the electronic structure, giving it a range of quantum properties.

Neupane's research group is using its specialized equipment for advanced-spectroscopic characterization of quantum materials to develop their work further.

"With the discovery of such an incredible material, we are at the brink of having a deeper understanding of the interplay of topological phases and developing the foundation for a new model from which all technology will be based off, essentially the silicon of a new era," Neupane said. [25]

Ytterbium: The quantum memory of tomorrow

Quantum communication and cryptography are the future of high-security communication. But many challenges lie ahead before a worldwide quantum network can be set up, including propagating the quantum signal over long distances. One of the major challenges is to create memories with the capacity to store quantum information carried by light. Researchers at the University of Geneva (UNIGE), Switzerland, in partnership with CNRS, France, have discovered a new material in which an element, ytterbium, can store and protect the fragile quantum information even while operating at high frequencies. This makes ytterbium an ideal candidate for future quantum networks, where the aim is to propagate the signal over long distances by acting as repeaters. These results are published in the journal *Nature Materials*.

Quantum cryptography today uses optical fibre over several hundred kilometres and is marked by its high degree of security: it is impossible to copy or intercept information without making it disappear.

However, the fact that it is impossible to copy the signal also prevents scientists from amplifying it to diffuse it over long distances, as is the case with the Wi-Fi network.

Finding the right material to produce quantum memories

Since the signal cannot be copied or amplified without it disappearing, scientists are currently working on how to make quantum memories capable of repeating it by capturing the photons and synchronising them so they can be diffused further and further. All that remains is to find the right material for making these quantum memories. "The difficulty is finding a material capable of isolating the quantum information conveyed by the photons from environmental disturbances so

that we can hold on to them for a second or so and synchronise them," explains Mikael Afzelius, a researcher in the Department of Applied Physics of UNIGE's Faculty of Sciences. "But a photon travels around 300,000 km in one second!" This meant the physicists and the chemists had to unearth a material that is very well isolated from disturbances but still capable of operating at high frequencies so that the photon can be stored and restored quickly—two characteristics that are often considered incompatible.

A "tipping point" for the "holy grail" of rare earths

Although laboratory-tested quantum memory prototypes already exist, including those based on rare earths such as europium or praseodymium, their speed is not yet high enough. "So, we turned our interest to a rare earth from the periodic table that had only received little attention so far: ytterbium," explains Nicolas Gisin, professor in the Department of Applied Physics in UNIGE's Faculty of Sciences and founder of ID Quantique. "Our goal was to find the ideal material for making quantum repeaters, which involves isolating atoms from their environment, which tends to disturb the signal," adds professor Gisin. And this seems to be the case with ytterbium!

The UNIGE and CNRS physicists discovered that, by subjecting this rare earth to very precise magnetic fields, the rare earth atom enters a state of insensitivity that cuts it off from the disturbances in its environment, making it possible to trap the photon so it can be synchronised. "We found a 'magic point' by varying the amplitude and direction of the magnetic field," say Alexey Tiranov, a researcher in the Department of Applied Physics at UNIGE, and Philippe Goldner, a researcher at the Chimie Paris research institute. "When this point is reached, the coherence times of the ytterbium atoms are increased by a factor of 1,000, while working at high frequencies!"

The benefits of ytterbium

The physicists are now in the process of building ytterbium-based quantum memories that can be used to quickly make transitions from one repeater to another while retaining the photon for as long as possible to enable the necessary synchronisation. "This material opens up a new field of possibilities for creating a global quantum network; it also underlines the importance of pursuing fundamental research in parallel with more applied research, such as devising a quantum memory," concludes Afzelius. [24]

Writing the future of rewritable memory

Scientists at the University of Alberta in Edmonton, Canada have created the most dense, solid-state memory in history that could soon exceed the capabilities of current hard drives by 1,000 times.

Faced with the question of how to respond to the ever-increasing needs of our data-driven society, the answer for a team of scientists was simple: more memory, less space. Finding the way to do that, however, was anything but simple, involving years of painstaking incremental advances in atomic-scale nanotechnology.

But their new discovery for atomic-scale rewritable memory—quickly removing or replacing single atoms—allows the creation of small, stable, dense memory at the atomic-scale.

"Essentially, you can take all 45 million songs on iTunes and store them on the surface of one quarter," said Roshan Achal, Ph.D. student in Department of Physics at the University of Alberta and lead author on the new research. "Five years ago, this wasn't even something we thought possible."

Previous discoveries were stable only at cryogenic conditions, meaning this new finding puts society light years closer to meeting the need for more storage for the current and continued deluge of data. One of the most exciting features of this memory is that it's road-ready for real-world temperatures, as it can withstand normal use and transportation beyond the lab.

"What is often overlooked in the nanofabrication business is actual transportation to an end user, that simply was not possible until now given temperature restrictions," continued Achal. "Our memory is stable well above room temperature and precise down to the atom."

Achal explained that immediate applications will be data archival. Next steps will be increasing readout and writing speeds, meaning even more flexible applications.

More memory, less space

Achal works with University of Alberta physics professor Robert Wolkow, a pioneer in the field of atomic-scale physics. Wolkow perfected the art of the science behind nanotip technology, which, thanks to Wolkow and his team's continued work, has now reached a tipping point, meaning scaling up atomic-scale manufacturing for commercialization.

"With this last piece of the puzzle now in-hand, atom-scale fabrication will become a commercial reality in the very near future," said Wolkow. Wolkow's Spin-off company, Quantum Silicon Inc., is hard at work on commercializing atom-scale fabrication for use in all areas of the technology sector.

To demonstrate the new discovery, Achal, Wolkow, and their fellow scientists not only fabricated the world's smallest maple leaf, they also encoded the entire alphabet at a density of 138 terabytes, roughly equivalent to writing 350,000 letters across a grain of rice. For a playful twist, Achal also encoded music as an atom-sized song, the first 24 notes of which will make any video-game player of the 80s and 90s nostalgic for yesteryear but excited for the future of technology and society. [23]

Single-atom magnets show stability needed for data storage

Individual holmium atoms adsorbed on magnesium oxide films can form highly stable magnets, according to a study done by Fabian Natterer at Switzerland's Federal Institute of Technology in Lausanne (EPFL) and colleagues. The team showed that the single-atom magnets can endure relatively high temperatures and strong external magnetic fields. The work could lead to the development of extremely high-density data storage devices.

Increasingly, data centres are coming under strain as we produce more and more information. One potential solution could lie in single-atom magnets, on which bits of data could be stored as long-lived magnetic quantum states. Previous studies have shown that these states can be easily manipulated, allowing data to be easily written and read out from the atoms. Furthermore, densely packing many atoms onto a surface would allow for vast amounts of data to be stored.

“Single-atom magnets offer an interesting perspective because quantum mechanics may offer shortcuts across their stability barriers that we could exploit in the future,” says Natterer. “This would be the last piece of the puzzle to atomic data recording.”

Significant challenges

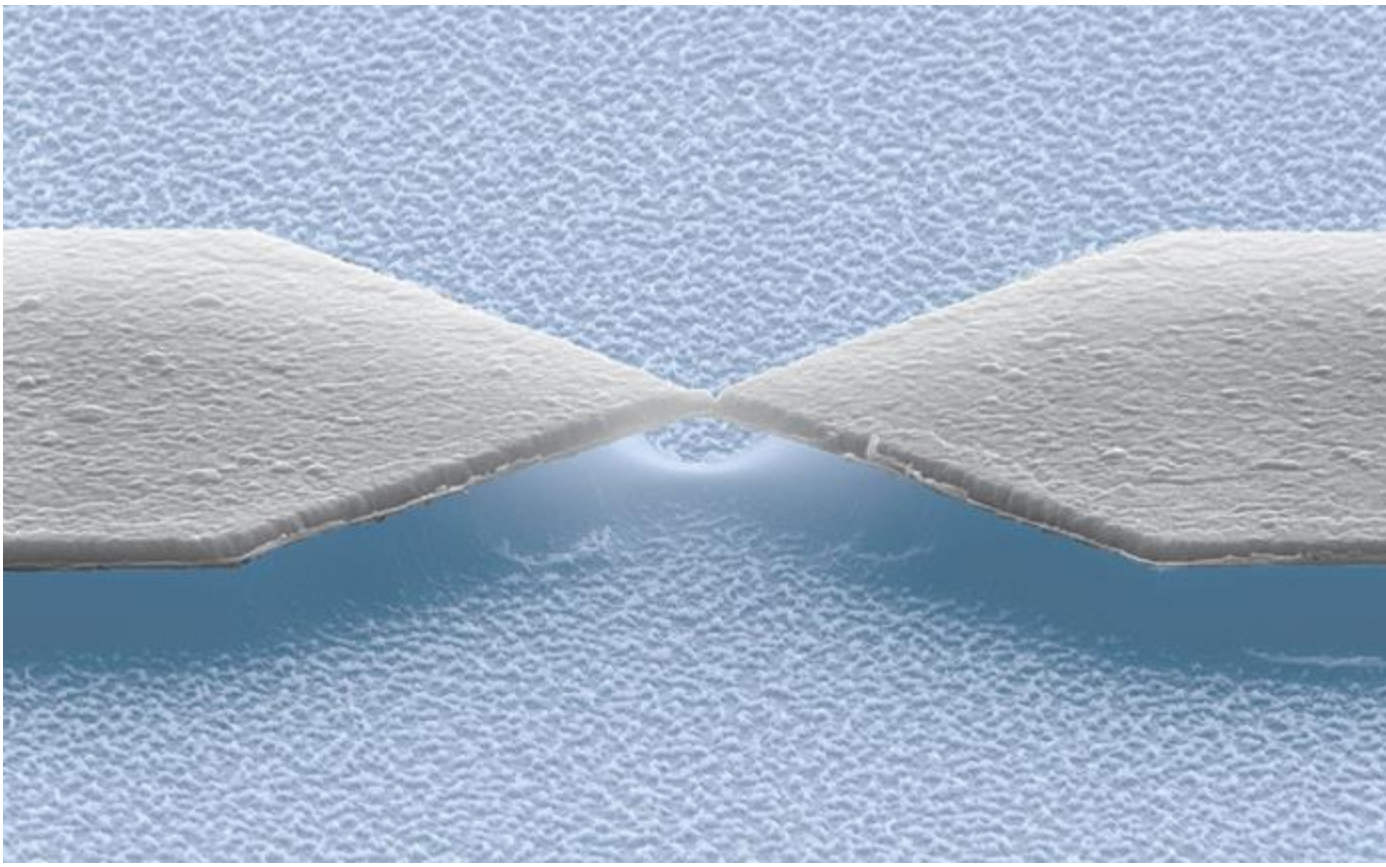
Single-atom magnets are still in the early stages of development, and the technology faces significant challenges relating to the thermal stability of the atoms’ magnetic quantum states. The coercivity of the magnets – their ability to resist demagnetization in external magnetic fields – is also low, which is not appropriate for data storage.

In their study, Natterer’s team used a scanning tunneling microscope to observe individual holmium atoms adsorbed to a film of magnesium oxide. This system that had previously been identified as collection of highly stable, single-atom magnets.

To test the atoms’ ability to withstand demagnetization, the team first subjected them to external magnetic fields up to 8 T – which is about 100,000 times the strength of Earth’s magnetic field. Remarkably, the atoms retained their magnetization for many minutes – the highest coercivity yet observed in individual atoms.

Hot and cold

Next, the atoms were exposed to temperatures of over 45 K. Their magnetic states remained stable up to 35::K and began to align with an external field at above 45 K. Although this is about 260 degrees below room temperature, it is very hot for single-atom magnets and reveals an ability to resist thermal perturbations.



Tiny switch toggles the position of a single atom

While the holmium atoms adsorbed on magnesium oxide are remarkably stable for a system of single magnets, Natterer and colleagues acknowledge that further studies are needed before the system can be implemented in commercial data storage. “We have demonstrated that the smallest bits can indeed be extremely stable,” Natterer continues. “Next, we need to learn how to write information to those bits more effectively to overcome the magnetic ‘trilemma’ of magnetic recording: stability, writability, and signal-to-noise ratio.”

The team also included scientists at Korea’s Institute for Basic Science and Ewha Womans University. The research is described in *Physical Review Letters*. [22]

A step closer to single-atom data storage

Despite the rise of solid-state drives, magnetic storage devices such as conventional hard drives and magnetic tapes are still very common. But as our data-storage needs are increasing at a rate of almost 15 million gigabytes per day, scientists are turning to alternative storage devices.

One of these are single-atom magnets: storage devices consisting of individual atoms stuck ("adsorbed") on a surface, each atom able to store a single bit of data that can be written and read using quantum mechanics. And because atoms are tiny enough to be packed together densely, single-atom storage devices promise enormous data capacities.

But although they are no longer science fiction, single-atom magnets are still in basic research, with many fundamental obstacles to be overcome before they can be implemented into commercial devices. EPFL has been at the forefront of the field, overcoming the issue of magnetic remanence, and showing that single-atom magnets can be used to read and write data.

In a new study published in *Physical Review Letters*, physicists at EPFL's Institute of Physics have used Scanning Tunneling Microscopy to demonstrate the stability of a magnet consisting of a single atom of holmium, an element they have been working with for years.

"Single-atom magnets offer an interesting perspective because quantum mechanics may offer shortcuts across their stability barriers that we could exploit in the future," says EPFL's Fabian Natterer who is the paper's first author. "This would be the last piece of the puzzle to atomic data recording."

View into the Scanning Tunneling Microscope used in the study. The tip reflection, seen at the top of the round silver crystal, is used to align the tip close to the sample surface. It is brought to within a few atomic radii to the surface …more

The scientists exposed the atom to extreme conditions that normally de-magnetize single-atom magnets, such as temperature and high magnetic fields, all of which would pose risks to future storage devices.

Using a Scanning Tunneling Microscope, which can "see" atoms on surfaces, the scientists found that the holmium atoms could retain their magnetization in a magnetic field exceeding 8 Tesla, which is around the strength of magnets used in the Large Hadron Collider. The authors describe this as "record-breaking coercivity", a term that describes the ability of a magnet to withstand an external magnetic field without becoming demagnetized.

Next, they turned up the heat: The researchers exposed a series of Holmium single-atom magnets to temperatures of up to 45 Kelvin, (-233.15 degrees Celsius), which, for single atoms, is like being in a sauna. The Holmium single-atom magnets remained stable up to a temperature of 35K. Only at around 45K, the magnets began to spontaneously align themselves to the applied magnetic field. This showed that they can withstand relatively high temperature perturbations and might point to the way forward for running single-atom magnets at more commercially viable temperatures.

"Research in the miniaturization of magnetic bits has focused heavily on magnetic bistability," says Natterer. "We have demonstrated that the smallest bits can indeed be extremely stable, but next we need to learn how to write information to those bits more effectively to overcome the magnetic 'trilemma' of magnetic recording: stability, writability, and signal-to-noise ratio." [21]

18-qubit entanglement sets new record

Physicists have experimentally demonstrated 18-qubit entanglement, which is the largest entangled state achieved so far with individual control of each qubit. As each qubit has two possible values, the 18 qubits can generate a total of 2^{18} (or 262,144) combinations of output states. Since quantum information can be encoded in these states, the results have potential applications anywhere quantum information processing is used.

The physicists, Xi-Lin Wang and coauthors at the University of Science and Technology of China, have published a paper on the new entanglement record in a recent issue of *Physical Review Letters*.

"Our paper reports 18-qubit entanglement that expands an effective Hilbert space to 262,144 dimensions (the largest so far) with full control of three degrees of freedom of six individual photons, including their paths, polarization, and orbital angular momentum," coauthor Chao-Yang Lu at the University of Science and Technology of China told *Phys.org*. "This represents the largest entanglement so far. Entangling an increasingly large number of qubits not only is of fundamental interest (i.e., pushing the physical limit, if there is one, in order to explore the boundary between quantum and classical, for example). But also, probably more importantly, entangling large numbers of qubits is the central task in quantum computation."

Generally, there are two ways to increase the number of effective qubits in an entangled state: use more particles, or exploit the particles' additional degrees of freedom (DoFs). When exploiting multiple DoFs, the entanglement is called "hyper-entanglement." So far, some of the largest entangled states have included 14 trapped ions with a single DoF, and five photons with two DoFs (which is equivalent to 10-qubit entanglement).

Although going beyond two DoFs presents greater technological challenges, in the new study the physicists developed new methods to generate scalable hyper-entanglement, producing an 18-qubit entangled state made from six photons with three DoFs.

"Controlling multiple DoFs is tricky, as it is necessary to touch one without disturbing any other," Lu explained. "To solve this, we develop methods for reversible quantum logic operations between the photon's different DoFs with precision and efficiencies both close to unity. We believe that our work creates a new and versatile platform for multi-photon quantum information processing with multiple DoFs."

Using additional DoFs has several advantages. For one, exploiting three DoFs instead of two doubles the information-carrying capacity of each photon from four to eight possible output states. In addition, a hyper-entangled 18-qubit state that exploits three DoFs is approximately 13 orders of magnitude more efficient than an 18-qubit state composed of 18 photons with a single DoF.

With these advantages, the physicists expect that the ability to achieve 18-qubit hyper-entanglement will lead to previously unprecedented areas of research, such as experimentally realizing certain codes for quantum computing, implementing quantum teleportation of high-dimensional quantum states, and enabling more extreme violations of local realism.

"Our work has created a new platform for optical quantum information processing with multiple DoFs," Lu said. "The ability to coherently control 18 qubits enables experimental access to previously unexplored regimes, for example, the realization of the surface code and the Raussendorf-Harrington-Goyal code for quantum error correction, and the teleportation of three DoFs of a single photon." [20]

Scientists pump up chances for quantum computing

University of Adelaide-led research has moved the world one step closer to reliable, high-performance quantum computing.

An international team has developed a ground-breaking single-electron "pump". The electron pump device developed by the researchers can produce one billion electrons per second and uses quantum mechanics to control them one-by-one. And it's so precise they have been able to use this device to measure the limitations of current electronics equipment.

This paves the way for future quantum information processing applications, including in defence, cybersecurity and encryption, and big data analysis.

"This research puts us one step closer to the holy grail—reliable, high-performance quantum computing," says project leader Dr. Giuseppe C. Tettamanzi, Senior Research Fellow, at the University of Adelaide's Institute for Photonics and Advanced Sensing.

Published in the journal *Nano Letters*, the researchers also report observations of electron behaviour that's never been seen before – a key finding for those around the world working on quantum computing.

"Quantum computing, or more broadly quantum information processing, will allow us to solve problems that just won't be possible under classical computing systems," says Dr. Tettamanzi.

"It operates at a scale that's close to an atom and, at this scale, normal physics goes out the window and quantum mechanics comes into play.

"To indicate its potential computational power, conventional computing works on instructions and data written in a series of 1s and 0s – think about it as a series of on and off switches; in quantum computing every possible value between 0 and 1 is available. We can then increase exponentially the number of calculations that can be done simultaneously."

This University of Adelaide team, in collaboration with the University of Cambridge, Aalto University in Finland, University of New South Wales, and the University of Latvia, is working in an emerging field called electron quantum optics. This involves controlled preparation, manipulation and measurement of single electrons. Although a considerable amount of work has been devoted world-wide to understand electronic quantum transport, there is much still to be understood and achieved.

"Achieving full control of electrons in these nano-systems will be highly beneficial for realistic implementation of a scalable quantum computer. We, of course, have been controlling electrons for the past 150 years, ever since electricity was discovered. But, at this small scale, the old physics rules can be thrown out," says Dr. Tettamanzi.

"Our final goal is to provide a flow of electrons that's reliable, continuous and consistent – and in this research, we've managed to move a big step towards realistic quantum computing.

"And, maybe equally exciting, along the way we have discovered new quantum effects never observed before, where, at specific frequencies, there is competition between different states for the capture of the same electrons. This observation will help advances in this game-changing field." [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 $\boldsymbol{E = h\nu}$ and $\boldsymbol{E = mc^2}$, $\boldsymbol{m = h\nu / c^2}$ that is the $\boldsymbol{m}$ depends only on the $\boldsymbol{\nu}$ 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 $\boldsymbol{m_o}$ 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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