Data Storage at the Molecular Level

Now scientists at the University of Manchester have proved that storing data with a class of molecules known as single-molecule magnets is more feasible than previously thought. [22]

The new work shows that collections of ultracold molecules can retain the information stored in them, for hundreds of times longer than researchers have previously achieved in these materials. [21]

Quantum entanglement can improve the sensitivity of a measurement, as has been demonstrated previously for atomic clocks and magnetic-field sensors. [20]

Thanks to a new fabrication technique, quantum sensing abilities are now approaching this scale of precision. [19]

For decades scientists have known that a quantum computer—a device that stores and manipulates information in quantum objects such as atoms or photons—could theoretically perform certain calculations far faster than today's computing schemes. [18]

Magnets and magnetic phenomena underpin the vast majority of modern data storage, and the measurement scales for research focused on magnetic behaviors continue to shrink with the rest of digital technology. [17]

Scientists have recently created a new spintronics material called bismuthene, which has similar properties to that of graphene. [16]

The expanding field of spintronics promises a new generation of devices by taking advantage of the spin degree of freedom of the electron in addition to its charge to create new functionalities not possible with conventional electronics. [15]

An international team of researchers, working at the Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) and UC Berkeley, fabricated an atomically thin material and measured its exotic and durable properties that make it a promising candidate for a budding branch of electronics known as "spintronics." [14]

The emerging field of spintronics aims to exploit the spin of the electron. [13]

In a new study, researchers measure the spin properties of electronic states produced in singlet fission – a process which could have a central role in the future development of solar cells. [12]

In some chemical reactions both electrons and protons move together. When they transfer, they can move concertedly or in separate steps. Light-induced reactions of this sort are particularly relevant to biological systems, such as Photosystem II where plants use photons from the sun to convert water into oxygen. [11]

EPFL researchers have found that water molecules are 10,000 times more sensitive to ions than previously thought. [10]

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

New ideas for interactions and particles: This paper examines the possibility to origin the Spontaneously Broken Symmetries from the Planck Distribution Law. This way we get a Unification of the Strong, Electromagnetic, and Weak Interactions from the interference occurrences of oscillators. Understanding that the relativistic mass change is the result of the magnetic induction we arrive to the conclusion that the Gravitational Force is also based on the electromagnetic forces, getting a Unified Relativistic Quantum Theory of all 4 Interactions.

Author: George Rajna

Major leap towards data storage at the molecular level

From smartphones to supercomputers, the growing need for smaller and more energy efficient devices has made higher density data storage one of the most important technological quests.

Now scientists at the University of Manchester have proved that storing data with a class of molecules known as single-molecule magnets is more feasible than previously thought.

The research, led by Dr David Mills and Dr Nicholas Chilton, from the School of Chemistry, is being published in Nature. It shows that magnetic hysteresis, a memory effect that is a prerequisite of any data storage, is possible in individual molecules at -213 °C. This is extremely close to the temperature of liquid nitrogen (-196 °C).

The result means that data storage with single molecules could become a reality because the data servers could be cooled using relatively cheap liquid nitrogen at -196°C instead of far more expensive liquid helium (-269 °C). The research provides proof-of-concept that such technologies could be achievable in the near future.

The potential for molecular data storage is huge. To put it into a consumer context, molecular technologies could store more than 200 terabits of data per square inch - that's 25,000 GB of information stored in something approximately the size of a 50p coin, compared to Apple's latest iPhone 7 with a maximum storage of 256 GB.

Single-molecule magnets display a magnetic memory effect that is a requirement of any data storage and molecules containing lanthanide atoms have exhibited this phenomenon at the highest temperatures to date. Lanthanides are rare earth metals used in all forms of everyday electronic devices such as smartphones, tablets and laptops. The team achieved their results using the lanthanide element dysprosium.

Dr Chilton says: 'This is very exciting as magnetic hysteresis in single molecules implies the ability for binary data storage. Using single molecules for data storage could theoretically give 100 times higher data density than current technologies. Here we are approaching the temperature of liquid nitrogen, which would mean data storage in single molecules becomes much more viable from an economic point of view.'

The practical applications of molecular-level data storage could lead to much smaller hard drives that require less energy, meaning data centres across the globe could become a lot more energy efficient.

For example, Google currently has 15 data centres around the world. They process an average of 40 million searches per second, resulting in 3.5 billion searches per day and 1.2 trillion searches per year. To deal with all that data, in July last year, it was reported that Google had approximately 2.5 million servers in each data centre and that number was likely to rise.

Some reports say the energy consumed at such centres could account for as much as 2 per cent of the world's total greenhouse gas emissions. This means any improvement in data storage and energy efficiency could also have huge benefits for the environment as well as vastly increasing the amount of information that can be stored.

Dr Mills adds: 'This advance eclipses the previous record which stood at -259 °C, and took almost 20 years of research effort to reach. We are now focused on the preparation of new molecules inspired by the design in this paper. Our aim is to achieve even higher operating temperatures in the future, ideally functioning above liquid nitrogen temperatures.' [22]

Ultracold molecules hold promise for quantum computing

Researchers have taken an important step toward the long-sought goal of a quantum computer, which in theory should be capable of vastly faster computations than conventional computers, for certain kinds of problems. The new work shows that collections of ultracold molecules can retain the information stored in them, for hundreds of times longer than researchers have previously achieved in these materials.

These two-atom molecules are made of sodium and potassium and were cooled to temperatures just a few ten-millionths of a degree above absolute zero (measured in hundreds of nanokelvins, or nK). The results are described in a report this week in Science, by Martin Zwierlein, an MIT professor of physics; Jee Woo Park, a former MIT graduate student; Sebastian Will, a former research scientist at MIT and now an assistant professor at Columbia University, and two others, all at the MIT-Harvard Center for Ultracold Atoms.

Many different approaches are being studied as possible ways of creating qubits, the basic building blocks of long-theorized but not yet fully realized quantum computers. Researchers have tried using superconducting materials, ions held in ion traps, or individual neutral atoms, as well as molecules of varying complexity. The new approach uses a cluster of very simple molecules made of just two atoms.

"Molecules have more 'handles' than atoms," Zwierlein says, meaning more ways to interact with each other and with outside influences. "They can vibrate, they can rotate, and in fact they can strongly interact with each other, which atoms have a hard time doing. Typically, atoms have to really meet each other, be on top of each other almost, before they see that there's another atom there to interact with, whereas molecules can see each other" over relatively long ranges. "In order to make these qubits talk to each other and perform calculations, using molecules is a much better idea than using atoms," he says.

Using this kind of two-atom molecules for quantum information processing "had been suggested some time ago," says Park, "and this work demonstrates the first experimental step toward realizing

this new platform, which is that quantum information can be stored in dipolar molecules for extended times."

"The most amazing thing is that [these] molecules are a system which may allow realizing both storage and processing of quantum information, using the very same physical system," Will says. "That is actually a pretty rare feature that is not typical at all among the qubit systems that are mostly considered today."

In the team's initial proof-of-principle lab tests, a few thousand of the simple molecules were contained in a microscopic puff of gas, trapped at the intersection of two laser beams and cooled to ultracold temperatures of about 300 nanokelvins. "The more atoms you have in a molecule the harder it gets to cool them," Zwierlein says, so they chose this simple two-atom structure.

The molecules have three key characteristics: rotation, vibration, and the spin direction of the nuclei of the two individual atoms. For these experiments, the researchers got the molecules under perfect control in terms of all three characteristics—that is, into the lowest state of vibration, rotation, and nuclear spin alignment.

"We have been able to trap molecules for a long time, and also demonstrate that they can carry quantum information and hold onto it for a long time," Zwierlein says. And that, he says, is "one of the key breakthroughs or milestones one has to have before hoping to build a quantum computer, which is a much more complicated endeavor."

The use of sodium-potassium molecules provides a number of advantages, Zwierlein says. For one thing, "the molecule is chemically stable, so if one of these molecules meets another one they don't break apart."

In the context of quantum computing, the "long time" Zwierlein refers to is one second—which is "in fact on the order of a thousand times longer than a comparable experiment that has been done" using rotation to encode the qubit, he says. "Without additional measures, that experiment gave a millisecond, but this was great already." With this team's method, the system's inherent stability means "you get a full second for free."

That suggests, though it remains to be proven, that such a system would be able to carry out thousands of quantum computations, known as gates, in sequence within that second of coherence. The final results could then be "read" optically through a microscope, revealing the final state of the molecules.

"We have strong hopes that we can do one so-called gate—that's an operation between two of these qubits, like addition, subtraction, or that sort of equivalent—in a fraction of a millisecond," Zwierlein says. "If you look at the ratio, you could hope to do 10,000 to 100,000 gate operations in the time that we have the coherence in the sample. That has been stated as one of the requirements for a quantum computer, to have that sort of ratio of gate operations to coherence times."

"The next great goal will be to 'talk' to individual molecules. Then we are really talking quantum information," Will says. "If we can trap one molecule, we can trap two. And then we can think about implementing a 'quantum gate operation'—an elementary calculation—between two molecular qubits that sit next to each other," he says.

Using an array of perhaps 1,000 such molecules, Zwierlein says, would make it possible to carry out calculations so complex that no existing computer could even begin to check the possibilities. Though he stresses that this is still an early step and that such computers could be a decade or more away, in principle such a device could quickly solve currently intractable problems such as factoring very large numbers—a process whose difficulty forms the basis of today's best encryption systems for financial transactions.

Besides quantum computing, the new system also offers the potential for a new way of carrying out precision measurements and quantum chemistry, Zwierlein says. [21]

Synopsis: Quantum Sensing of Magnetic Fields

Quantum entanglement can improve the sensitivity of a measurement, as has been demonstrated previously for atomic clocks and magnetic-field sensors. A new experiment with a cloud of cold atoms is able to measure a weak magnetic-field signal with a 25% reduction in experimental noise, thanks to entanglement of the atoms. The method involves a sequence of quantum nondemolition (QND) measurements, which track the effect of the magnetic signal on the atoms' spins without destroying their quantum coherence. The advantage of this technique is that it can measure arbitrary field waveforms (sine wave, chirp, etc.), which might allow it to pinpoint the magnetic signal coming from the firing of a single neuron.

In their experiment, Martin Ciurana from The Institute of Photonic Sciences (ICFO), Spain, and his colleagues start by trapping around a million rubidium atoms and chilling them to 16 microkelvin. A strong magnetic field polarizes the spins of the atoms, while at the same time a weaker, time-varying magnetic field—which is the signal to be detected—perturbs the spins in an orthogonal direction to the spin polarization. To probe the atoms, the team fires a laser pulse into the cloud and records a rotation in the light's polarization. This qualifies as a QND measurement, as it provides information on the perturbed state without disturbing it. The pulse also entangles the atoms with each other. The researchers allow this entangled system to evolve for several hundred microseconds before performing a second QND measurement with a laser pulse. By combining the two measurements, the team measures the amplitude of the magnetic waveform at a level of sensitivity below the standard quantum limit set by quantum noise in the measurements.

This research is published in Physical Review Letters. [20]

Researchers demonstrate new way to produce high-density clusters of aligned quantum sensors in diamond

Imagine a sensor so sensitive it can detect changes in the proton concentration of a single protein, within a single cell. This level of insight would reveal elusive quantum-scale dynamics of that protein's function, potentially even in real time, but demands a sensor with controllable features at a similar scale.

Thanks to a new fabrication technique, quantum sensing abilities are now approaching this scale of precision. As they report this week in Applied Physics Letters, researchers in Japan have reproducibly

formed an aligned ensemble of quantum sensors called nitrogen vacancy (NV) centers, just nanometers from its substrate's surface.

Verified by nanoscale nuclear magnetic resonance (NMR) measurements, these results mark a clear path towards atomic level design of quantum sensors with larger surface areas than typically achievable. This is the first demonstration of this nanoscale NMR measurement with perfectly aligned, high-density NV centers near the surface, marking a huge advance for quantum magnetometry research.

"The way to combine both high counts and high contrast is to have the alignment, because when you have the alignment you basically have the benefit of the single NVs combined with the high counts obtained from the ensemble NV centers," said Hitoshi Ishiwata from the Tokyo Institute of Technology and lead author of the paper. "So that's what we basically did, really close to the surface—within 10 nanometers—and we demonstrated that with a SIMS [Secondary Ion Mass Spectrometry] measurement, as well as measuring nano NMR, which shows you the approximation of the distance of NVs from the surface."

NV centers, already a popular tool in the world of quantum sensing, are specific kinds of impurities in the crystal structure of diamond. For a single unit of diamond's otherwise purely carbon configuration, the NV center consists of a nitrogen atom adjacent to a missing (vacant) atom in the crystal's lattice. This defect can occur in one of four possible locations in the unit crystal, and each provides a single-photon signal whose spectral signature is nuclear spin-dependent.

The new technique uses a combination of chemical vapor deposition (CVD) and directional polishing to control how the NVs form in the lattice. For their diamond substrate, which has a commonly aligned surface, where the lattice is oriented along the same crystollagraphic plane (called 111 in this case), Ishiwata and his colleagues achieved ensembles of NVs all with the same orientation. For a substrate measuring about 10 microns across, just less than the width of a human hair, their method can produce somewhere around 10,000 such centers within 10 nanometers from surface.

NVs in the same respective locations of their crystal units and so close to the surface, the group could conduct nanoscale NMR detection of the fluorine in oil making contact with the substrate. The reliability of their fabrication method has (literally) far reaching applications for wide field measurements, ensuring the high contrast detection over relatively large sample areas.

"The other benefit of high density NV centers with alignment is to perform wide field imaging with high sensitivity," Ishiwata said. "Before it was impossible to have high sensitivity for wide field imaging due to the difficulty of obtaining alignment of NV centers with high density. With our technique, high contrast wide field imaging with high signal to noise ratio is now possible, which leads to high sensitivity wide field imaging."

As the group continues to look for ways to further improve the method, they are also looking to explore applications of these ensembles in time resolved sensing, using pulsed lasers to provide real-time proton information of dynamic samples. Ishiwata himself was particularly excited about the possibilities for understanding biological cells like never before.

"A future application of this material is the observation of individual cell membranes because our material is suited for observing nanoscale NMR on the volume scale of 17 cubic nanometers, which

is comparable to the thickness of cell membranes (~5 nanometers)," Ishiwata said. "So we could use this material and measurement technique for locally probing nanoscale activity of proteins that exists in cell membrane with high sensitivity." [19]

Quantum computing building blocks

For decades scientists have known that a quantum computer—a device that stores and manipulates information in quantum objects such as atoms or photons—could theoretically perform certain calculations far faster than today's computing schemes. But building the "parts" for a quantum computer is a monumental research task. One promising approach involves using the quantum "spin" property of nitrogen-vacancy (NV) centers in diamonds to store and process data. But properly placing these centers is a major challenge. Recently researchers constructed chains of NV centers in diamond with more precision than any previous effort.

Diamond nanophotonics technology is a major contender for future optical computers. This work provides a wholly suitable pathway for the large-scale production of quantum logic gates for quantum computers that that approach the power of the human mind.

Scientists at the Massachusetts Institute of Technology created a wholly suitable pathway for the large-scale production of quantum logic gates. These gates are a critical component for quantum computing architectures. At the Center for Functional Nanomaterials, the researchers fabricated the silicon-based stencils. They used the stencils to pattern the NV centers. The stencils possessed features as small as 2 nanometers—nearly 10 times smaller than any previous demonstration. These devices are compatible with densities required for quantum computers.

Within diamonds, nitrogen vacancies have electron spin states that could be useful for future quantum computers. The NV electron spin triplet levels can be readily manipulated to create long-lasting states (exceeding milliseconds) at room temperature and even longer states (approaching one second) at the temperature of liquid nitrogen. To extend this approach to create more qubits, researchers devised a fabrication technique that produced well-spaced ensembles of several NVs. The spacing is required to allow the states to couple so they last longer. Their technique is based on masks produced from 270-nanometer-thick, silicon-based stencils, enabling 1-nanometer defects to be packed onto the surface.

The team's approach combined the low full-width half-maximum of the atomic force microscopy tip implantation with the quick patterning available using electron beam lithography. The team used the stencils to reach a regime where the nitrogen distribution is no longer limited by the size of the opening on the stencil but by the basic process of implanted nitrogen scattering in the diamond lattice. The team's work opens the door to scalable creation of isolated spin ensembles for next-generation quantum computing. [18]

Pulses of electrons manipulate nanomagnets and store information

Magnets and magnetic phenomena underpin the vast majority of modern data storage, and the measurement scales for research focused on magnetic behaviors continue to shrink with the rest of digital technology. Skyrmions, for example, are a kind of nanomagnet, comprised of a spin-correlated ensemble of electrons acting as a topological magnet on certain microscopic surfaces. The

precise properties, like spin orientation, of such nanomagnets can store information. But how might you go about moving or manipulating these nanomagnets at will to store the data you want?

New research from a German-U.S. collaboration now demonstrates such read/write ability using bursts of electrons, encoding topological energy structures robustly enough for potential data storage applications. As the group reports this week in Applied Physics Letters, the magnetization of these ensemble excitations, or quasiparticles, is controlled by tailoring the profile of the electron pulses, varying either the total number of electrons or their width in space.

"The work shows how magnetization of nanoscale magnets can be steered by intense ultrashort electron pulses," said Alexander Schäffer, a doctoral student at Martin-Luther-Universität Halle-Wittenberg in Halle, Germany, and lead author of the paper. "Experiments at SLAC already demonstrated the ultimate speed limit of magnetic switching with this scheme. Here we show that tailored electron pulses can swiftly write, erase or switch topologically protected magnetic textures such as skyrmions."

So far, Schäffer says there are only a few realized applications of these skyrmions, which are relatively new to the forefront of solid state physics, but their properties and the current research capabilities make them ripe for next generation technologies.

Magnetization dynamics leading to four skyrmions in the inside of a domain-wall ring are protected against fluctuations outside the ring. The sample covers an area of (800x800) nm^2. Credit: Schäffer et al/AIPP

"In the tradition of the field of spin dynamics in nanostructures, I still appreciate the idea of non-volatile (long-term) memory devices, as the community of spintronics is also pursuing," he said. "The nice interplay between the mathematical concept of topological energy barriers and the physical transport properties of skyrmions, which are highly mobile, are the outstanding aspects for me."

Not only are these magnetic excitations controllable, but the team's results confirm many of the dynamic understandings provided by theory. Moreover, their results demonstrate potential for achieving similar topological charge transcription by way of laser pulses, whose lower and mass-free energy offer a number of practical benefits.

"These quasiparticles are robust against external perturbations, and hence are usually difficult to manipulate, and have a high potential for applications in data storage and computing," Schäffer said. "I was positively surprised about the nice accordance between experiment, analytics and numerical results, which gave me a good feeling in continuing this path. A second point was the finding that textures can be written with much lower beam intensity using tightly focused electron pulses. This brings their technological exploitation within reach as the required high-energy ultrafast electron microscopy setup is currently being developed at SLAC and other places worldwide."

This significant step lends itself to many more in the evolution from this generation's cutting-edge research to next generation's hard drives. As they continue to build on their research, Schäffer and his collaborators are looking toward broader applicability in a number of ways.

"Further development in the setups is required to be able to write skyrmionic structures on extended films, where we can't make any profit of geometric confinements like in the nanodisks,"

Schäffer said. "The next steps are mani-fold. Of course, an experimental realization is what we strive for with our experimental colleagues, especially the question of how good the switching-behavior between different topological states can be covered by our calculations. A complete simulation of laser-irradiated TEM of magnetic samples is one of our big goals at the moments." [17]

New Spintronics Material Could Advance Quantum Computing

Scientists have recently created a new spintronics material called bismuthene, which has similar properties to that of graphene. Because it works at room temperature instead of the incredibly cold, as low as -450 F, bismuthene makes the idea of spintronics information transmission much more realistic. Bismuthene is a combination of silicon carbide substrate and bismuth atoms.

If you've never heard of spintronics before, it is a form of nanoscale electronics based on the electron's spin rather than its charge. If made viable, spintronics could change the world of electronics by providing faster data transfers, low energy consumption, and having four states, rather than only two states as in traditional computing. Because of it quantum state manipulation, bismuthene has the potential accelerate computation and free manufacturers from the difficulties involved in the fabrication of sub-10nm semiconductors.

Developed in Germany by a team of scientists from the University of Wurzberg, bismuthene consists of a layer of bismuth, only as thick as a single atom, on top of a silicon carbide substrate. When laid on top of the substrate the bismuth forms a honeycomb pattern, the same as graphene. But, unlike graphene, bismuthene creates a chemical bond with the silicon carbide, which remains conductive and also insulative in the center.

For spintronics to function, there cannot be any short circuits through the substrate or material, therefore the insulative center is key.

Although this is very new research, the research team have had run their own successful experiments and are optimistic about the future. However, it is doubtful that we will see bismuthene in commercial electronics anytime soon, much more work is needed to develop the material into usable products but when they do they are sure to be exceptional. [16]

Quantifying the crossover from surface to bulk properties in important spintronic materials

The expanding field of spintronics promises a new generation of devices by taking advantage of the spin degree of freedom of the electron in addition to its charge to create new functionalities not possible with conventional electronics. The giant magnetoresistance (GMR) effect (2007 Nobel Prize in Physics) is a paradigmatic example of a spintronics application. As the interface between the magnetic and non-magnetic materials is a key component of any such device, it is crucial to characterise and understand both the surface and bulk electronic and magnetic properties.

In a recent publication in Nature Communications, a joint venture between theorists, experimentalists and sample growers led by a group from National Research Council (CNR) Trieste, Italy, reports a systematic photoemission spectroscopy study of two representative materials for spintronics applications, (Ga,Mn)As and La1-xSrxMnO3. Using the photon energy of the incident

synchrotron radiation from the Surface and Interface Structural Analysis beamline (I09) at Diamond Light Source as a depth-profiling tool, they were able to quantify the variation in the strength of the magnetic order and the electrical conduction from the surface down into the bulk of the material. This study establishes the different properties of the surfaces compared with the bulk and the characteristic 'critical' depths needed to restore bulk properties, which are crucial pieces of information for the design of any spintronic devices based on these materials.

Materials challenge for spintronics applications

Modern electronics rely on the ability to control currents in solid state devices such as transistors and diodes. However, in addition to their charge, electrons possess another quantum mechanical property known as 'spin', which is responsible for the phenomenon of magnetism. In materials used for conventional electronics, such as silicon, the spin is a redundant degree of freedom, but the goal of the emerging field of spintronics is to be able to create devices in which both the charge and spin currents can be controlled simultaneously, allowing for a new generation of logic and memory devices.

Any potential spintronic device will need to incorporate a material that is both magnetic and electrically conducting, enabling the propagation of a 'spin current'. Broadly speaking, two 'doping' approaches to this materials challenge are conceivable – either by introducing magnetic elements such as manganese into an otherwise non-magnetic semiconductor, such as (Ga,Mn)As, or by introducing extra carriers by, for example, replacing some lanthanum atoms with a strontium one, thereby donating one additional electron in La1-xSrxMnO3; in both cases, one may induce magnetism. By control of the chemical composition, it is possible to tune and optimise the bulk properties of the material, including the carrier density and the critical temperature below which the material is magnetic (or to be precise, ferromagnetic). However, if these materials are to be used in practical devices, they will be used in interfaces with other components, and therefore it is crucially important to also understand how the properties of the surfaces of the material may differ from the behaviour deep in the bulk of the sample. Moreover, it is paramount to quantitatively determine the length scale over which the fully bulk-like properties develop.

Depth-dependent information from photoelectron spectroscopy at I09

Experimentally extracting depth-dependent information on the metallic character of the electrons is no easy feat. However, theoretical calculations performed as part of this study established that the degree of 'metallicity' could be indirectly probed via a measurement known as photoemission spectroscopy. These calculations were carried out by Professor Gerrit van der Laan from Diamond and Professor Munetaka Taguchi from Spring8 and NAIST, Japan. In this technique, a beam of X-rays is shone onto the sample of interest, kicking out electrons which are referred to as the photoelectrons. The energy profile of these photoelectrons reveals information on the electronic states inside the sample, and it was shown that a narrow 'satellite' feature located next to the more conventional peaks arising from electrons in a particular '2p' shell of manganese could be interpreted as a clear fingerprint of the presence of metallic behaviour.

Since the photoelectrons have to exit the sample through its surface in order to be detected, one might expect that the technique would be most sensitive to electron states near the surface of the

sample. This is generally true, but by tuning the energy of the incoming X-ray beam one can vary the characteristic length scale which is being probed in the measurement. With higher energy X-rays, the ejected photoelectrons also have higher energy, and can exit the sample from deeper inside the material.

This is where the Surface and Interface Structural Analysis beamline (I09) at Diamond Light Source comes in. I09 is a highly versatile beamline, in which photoelectron spectroscopy measurements may be performed with excellent resolution, high beam intensity, and—crucially for this study—a uniquely wide range of X-ray energies. These features give the researchers the opportunity to measure either surface sensitive at low energies, or to use high energies to see deep into the bulk of the sample, with all other experimental considerations held constant (note that 'deep' in this context is still about 500 times smaller than the width of a human hair!). "In our measurements at I09 we were able to quantify and track the fine details of the electronic structure within the same material as a function of depth, from the surface into the bulk" described Tommaso Pincelli, a PhD student from CNR, Trieste and a lead author of the study.

Material-dependent length scales – but the surface is always different

By performing these energy-dependent photoelectron spectroscopy measurements on (Ga,Mn)As and La1-xSrxMnO3, the researchers were able to demonstrate that the metallic behaviour in the bulk was strongly suppressed at the surface. The two different materials showed different characteristic length scales needed to develop bulk-like properties: 1.2 nm and 4 nm respectively. These are crucial parameters for designing any spintronic devices based on these materials: it is not only necessary that one can engineer the physical atomic structure with sub-nanometre precision, but the variation of electronic properties over these length scales is also important. "These electronic length scales are quite significant and must be taken into account in the design of any future devices" concluded Dr Giancarlo Panaccione, the corresponding author of the study. [15]

X-ray technique provides a new window into exotic properties of an atomically thin material

An international team of researchers, working at the Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) and UC Berkeley, fabricated an atomically thin material and measured its exotic and durable properties that make it a promising candidate for a budding branch of electronics known as "spintronics."

The material - known as 1T'-WTe2 - bridges two flourishing fields of research: that of so-called 2-D materials, which include monolayer materials such as graphene that behave in different ways than their thicker forms; and topological materials, in which electrons can zip around in predictable ways with next to no resistance and regardless of defects that would ordinarily impede their movement.

At the edges of this material, the spin of electrons - a particle property that functions a bit like a compass needle pointing either north or south - and their momentum are closely tied and predictable.

This latest experimental evidence could elevate the material's use as a test subject for next-gen applications, such as a new breed of electronic devices that manipulate its spin property to carry and store data more efficiently than present-day devices. These traits are fundamental to spintronics.

The material is called a topological insulator because its interior surface does not conduct electricity, and its electrical conductivity (the flow of electrons) is restricted to its edges.

"This material should be very useful for spintronics studies," said Sung-Kwan Mo, a physicist and staff scientist at Berkeley Lab's Advanced Light Source (ALS) who co-led the study, published today in Nature Physics.

2-D material's traits could send electronics R&D spinning in new directions

Beamline 10.0.1 at Berkeley Lab's Advanced Light Source enables researchers to both create and study the properties of atomically thin materials. Credit: Roy Kaltschmidt/Berkeley Lab

"The flow of electrons is completely linked with the direction of their spins, and is limited only to the edges of the material," Mo said. "The electrons will travel in one direction, and with one type of spin, which is a useful quality for spintronics devices." Such devices could conceivably carry data more fluidly, with lesser power demands and heat buildup than is typical for present-day electronic devices.

"We're excited about the fact that we have found another family of materials where we can both explore the physics of 2-D topological insulators and do experiments that may lead to future applications," said Zhi-Xun Shen, a professor in Physical Sciences at Stanford University and the Advisor for Science and Technology at SLAC National Accelerator Laboratory who also co-led the research effort. "This general class of materials is known to be robust and to hold up well under various experimental conditions, and these qualities should allow the field to develop faster," he added.

The material was fabricated and studied at the ALS, an X-ray research facility known as a synchrotron. Shujie Tang, a visiting postdoctoral researcher at Berkeley Lab and Stanford University, and a co-lead author in the study, was instrumental in growing 3-atom-thick crystalline samples of the material in a highly purified, vacuum-sealed compartment at the ALS, using a process known as molecular beam epitaxy.

The high-purity samples were then studied at the ALS using a technique known as ARPES (or angle-resolved photoemission spectroscopy), which provides a powerful probe of materials' electron properties.

"After we refined the growth recipe, we measured it with ARPES. We immediately recognized the characteristic electronic structure of a 2-D topological insulator," Tang said, based on theory and predictions. "We were the first ones to perform this type of measurement on this material."

But because the conducting part of this material, at its outermost edge, measured only a few nanometers thin - thousands of times thinner than the X-ray beam's focus - it was difficult to positively identify all of the material's electronic properties.

So collaborators at UC Berkeley performed additional measurements at the atomic scale using a technique known as STM, or scanning tunneling microscopy. "STM measured its edge state directly, so that was a really key contribution," Tang said.

The research effort, which began in 2015, involved more than two dozen researchers in a variety of disciplines. The research team also benefited from computational work at Berkeley Lab's National Energy Research Scientific Computing Center (NERSC).

Two-dimensional materials have unique electronic properties that are considered key to adapting them for spintronics applications, and there is a very active worldwide R&D effort focused on tailoring these materials for specific uses by selectively stacking different types.

"Researchers are trying to sandwich them on top of each other to tweak the material as they wish - like Lego blocks," Mo said. "Now that we have experimental proof of this material's properties, we want to stack it up with other materials to see how these properties change."

A typical problem in creating such designer materials from atomically thin layers is that materials typically have nanoscale defects that can be difficult to eliminate and that can affect their performance. But because 1T'-WTe2 is a topological insulator, its electronic properties are by nature resilient.

"At the nanoscale it may not be a perfect crystal," Mo said, "but the beauty of topological materials is that even when you have less than perfect crystals, the edge states survive. The imperfections don't break the key properties."

Going forward, researchers aim to develop larger samples of the material and to discover how to selectively tune and accentuate specific properties. Besides its topological properties, its "sister materials," which have similar properties and were also studied by the research team, are known to be light-sensitive and have useful properties for solar cells and for optoelectronics, which control light for use in electronic devices. [14]

Device design allows ten-fold increase in spin currents

An electron carries electrical charge and spin that gives rise to a magnetic moment and can therefore interact with external magnetic fields. Conventional electronics are based on the charge of the electron. The emerging field of spintronics aims to exploit the spin of the electron. Using spins as elementary units in computing and highly efficient electronics is the ultimate goal of spintronic science because of spintronics minimal energy use. In this study, researchers manipulated and amplified the spin current through the design of the layered structures, a vital step towards this goal.

For cell phones, computers, and other electronic devices, a major shortcoming is the generation of heat when electrons move around the electronic circuits. The energy loss significantly reduces the device efficiency. Ultimately, the heat limits the packing of components in high-density micro-chips. Spintronics' promise is to eliminate this energy loss. It does so by just moving the electron spin without moving the electrons. Using design strategies such as those identified by this research could result in highly energy-efficient spintronics to replace today's electronics.

An important obstacle to realizing spintronics is the amplification of small spin signals. In conventional electronics, amplification of an electron current is achieved using transistors. Recently, researchers at Johns Hopkins University demonstrated that small spin currents can be amplified by inserting thin films of antiferromagnetic (materials in which the magnetic moments are canceled) insulator materials into the layered structures, effectively producing a spin-transistor. Scientists used thin films of antiferromagnetic insulators, such as nickel and cobalt oxide, sandwiched between ferrimagnetic insulator yttrium iron garnet (YIG) and normal metal films. With such devices, they showed that the pure spin current thermally injected from YIG into the metal can be amplified up to ten-fold by the antiferromagnetic insulator film. The researchers found that spin fluctuation of the antiferromagnetic insulating layer enhances the spin current. They also found that the amplification is linearly proportional to spin mixing conductance of the normal metal and the YIG. The experiments demonstrated this effect for various metals. Further, the study showed that the spin current amplification is proportional to the spin mixing conductance of YIG/metal systems for different metals. Calculations of the spin current enhancement and spin mixing conductance provided qualitative agreement with the experimental observations. [13]

Researchers road-test powerful method for studying singlet fission

In a new study, researchers measure the spin properties of electronic states produced in singlet fission – a process which could have a central role in the future development of solar cells.

Physicists have successfully employed a powerful technique for studying electrons generated through singlet fission, a process which it is believed will be key to more efficient solar energy production in years to come.

Their approach, reported in the journal Nature Physics, employed lasers, microwave radiation and magnetic fields to analyse the spin of excitons, which are energetically excited particles formed in molecular systems.

These are generated as a result of singlet fission, a process that researchers around the world are trying to understand fully in order to use it to better harness energy from the sun. Using materials exhibiting singlet fission in solar cells could make energy production much more efficient in the future, but the process needs to be fully understood in order to optimize the relevant materials and design appropriate technologies to exploit it.

In most existing solar cells, light particles (or photons) are absorbed by a semiconducting material, such as silicon. Each photon stimulates an electron in the material's atomic structure, giving a single electron enough energy to move. This can then potentially be extracted as electrical current.

In some materials, however, the absorption of a single photon initially creates one higher-energy, excited particle, called a spin singlet exciton. This singlet can also share its energy with another molecule, forming two lower-energy excitons, rather than just one. These lower-energy particles are called spin "triplet" excitons. Each triplet can move through the molecular structure of the material and be used to produce charge.

The splitting process - from one absorbed photon to two energetic triplet excitons - is singlet fission. For scientists studying how to generate more solar power, it represents a potential bargain - a two-

for-one offer on the amount of electrical current generated, relative to the amount of light put in. If materials capable of singlet fission can be integrated into solar cells, it will become possible to generate energy more efficiently from sunlight.

But achieving this is far from straightforward. One challenge is that the pairs of triplet excitons only last for a tiny fraction of a second, and must be separated and used before they decay. Their lifespan is connected to their relative "spin", which is a unique property of elementary particles and is an intrinsic angular momentum.

Studying and measuring spin through time, from the initial formation of the pairs to their decay, is essential if they are to be harnessed.

In the new study, researchers from the University of Cambridge and the Freie Universität Berlin (FUB) utilised a method that allows the spin properties of materials to be measured through time. The approach, called electron spin resonance (ESR) spectroscopy, has been used and improved since its discovery over 50 years ago to better understand how spin impacts on many different natural phenomena.

It involves placing the material being studied within a large electromagnet, and then using laser light to excite molecules within the sample, and microwave radiation to measure how the spin changes over time. This is especially useful when studying triplet states formed by singlet fission as these are difficult to study using most other techniques.

Because the excitons' spin interacts with microwave radiation and magnetic fields, these interactions can be used as an additional way to understand what happens to the triplet pairs after they are formed. In short, the approach allowed the researchers to effectively watch and manipulate the spin state of triplet pairs through time, following formation by singlet fission.

The study was led by Professor Jan Behrends at the Freie Universität Berlin (FUB), Dr Akshay Rao, a College Research Associate at St John's College, University of Cambridge, and Professor Neil Greenham in the Department of Physics, University of Cambridge.

Leah Weiss, a Gates-Cambridge Scholar and PhD student in Physics based at Trinity College, Cambridge, was the paper's first author. "This research has opened up many new questions," she said. "What makes these excited states either separate and become independent, or stay together as a pair, are questions that we need to answer before we can make use of them."

The researchers were able to look at the spin states of the triplet excitons in considerable detail. They observed pairs had formed which variously had both weakly and strongly-linked spin states, reflecting the co-existence of pairs that were spatially close and further apart. Intriguingly, the group found that some pairs which they would have expected to decay very quickly, due to their close proximity, actually survived for several microseconds.

"Finding those pairs in particular was completely unexpected," Weiss added. We think that they could be protected by their overall spin state, making it harder for them to decay. Continued research will focus on making devices and examining how these states can be harnessed for use in solar cells."

Professor Behrends added: "This interdisciplinary collaboration nicely demonstrates that bringing together expertise from different fields can provide novel and striking insights. Future studies will need to address how to efficiently split the strongly-coupled states that we observed here, to improve the yield from singlet fission cells."

Beyond trying to improve photovoltaic technologies, the research also has implications for wider efforts to create fast and efficient electronics using spin, so-called "spintronic" devices, which similarly rely on being able to measure and control the spin properties of electrons. [12]

Using light to move electrons and protons

In some chemical reactions both electrons and protons move together. When they transfer, they can move concertedly or in separate steps. Light-induced reactions of this sort are particularly relevant to biological systems, such as Photosystem II where plants use photons from the sun to convert water into oxygen.

To better understand how light can lead to the transfer of protons in a chemical reaction, a group of researchers from the University of North Carolina, Shanxi University in China, and Memorial University in Newfoundland have conducted adsorption studies on a new family of experiments to observe the transition that occurs when protons transfer between hydrogen-bonded complexes in solution . They provide evidence for new optical transitions characteristic of the direct transfer of a proton. This report recently appeared in the Proceedings of the National Academy of Sciences.

N-methyl-4,4'-bipyridinium cation (MQ+) serves as proton acceptor, where a proton will add to the non-methylated pyridinium amine. If proton transfer occurs, then MQ+ will form a radical cation (MQH+•) whose absorbance spectra in the UV/visible range can be compared to N, N'-dimethyl-4, 4'-bypyridinium (MV2+).

By using ultrafast laser flash photolysis measurements, they found direct evidence for a low energy absorption band between p-methoxyphenyl and the mehylviologen acceptor, MQ+. It appears at 360 nm and as early as 250 fs after the laser pulse. Based on these properties, it is clearly the product of proton transfer from the phenol to give MeOPhO•—H-MQ+.

The appearance of this reaction involving the transfer of both an electron and proton after absorbing a single photon is supported by the vibrational coherence of the radical cation and by it characteristic spectral properties. By inference, related transitions, which are often at low intensities, could play an important role in the degradation of certain biological molecules, such as DNA.

The appearance of these absorption bands could have theoretical significance. They demonstrate a way to use simple spectroscopic measurements to explore the intimate details of how these reactions occur in nature. This provides new physical insight into processes that could be of broad biological and chemical relevance. [11]

A single ion impacts a million water molecules

EPFL researchers have found that water molecules are 10,000 times more sensitive to ions than previously thought.

Water is simple and complex at the same time. A single water molecule (H2O) is made up of only 3 atoms. Yet the collective behavior of water molecules is unique and continues to amaze us. Water molecules are linked together by hydrogen bonds that break and form several thousands of billions of times per second. These bonds provide water with unique and unusual properties. Living organisms contain around 60% water and salt. Deciphering the interactions among water, salt and ions is thus fundamentally important for understanding life.

Not 100 but 1,000,000 molecules react

Researchers at EPFL's Laboratory for fundamental BioPhotonics, led by Sylvie Roke, have probed the influence of ions on the structure of water with unprecedentedly sensitive measurements. According to their multi-scale analyses, a single ion has an influence on millions of water molecules, i.e. 10,000 times more than previously thought. In an article appearing in Science Advances, they explain how a single ion can "twist" the bonds of several million water molecules over a distance exceeding 20 nanometers causing the liquid to become "stiffer". "Until now it was not possible to see beyond a hundred molecules. Our measurements show that water is much more sensitive to ions than we thought," said Roke, who was also surprised by this result.

The molecules line up around the ions

Water molecules are made up of one negatively charged oxygen atom and two positively charged hydrogen atoms. The Mickey Mouse-shaped molecule therefore does not have the same charge at its center as at its extremities. When an ion, which is an electrically charged atom, comes into contact with water, the network of hydrogen bonds is perturbed. The perturbation spreads over millions of surrounding molecules, causing water molecules to align preferentially in a specific direction. This can be thought of as water molecules "stiffening their network" between the various ions.

From atomistic to macroscopic length scales

Water's behavior was tested with three different approaches: ultrafast optical measurements, which revealed the arrangement of molecules on the nanometric scale; a computer simulation on the atomic scale; and measurement of the water's surface structure and tension, which was done at the macroscopic level. "For the last method, we simply dipped a thin metal plate into the water and pulled gently using a tensiometer to determine the water's resistance," said Roke. "We observed that the presence of a few ions makes it easier to pull the plate out, that is, ions reduce the surface resistance of water. This strange effect had already been observed in 1941, but it remained unexplained until now. Through our multiscale analysis we were able to link it to ion-induced stiffening of the bulk hydrogen bond network: a stiffer bulk results in a comparatively more flexible surface."

Testing different salts and different "waters"

The researchers carried out the same experiment with 21 different salts: they all affected water in the same way. Then they studied the effect of ions on heavy water, whose hydrogen atoms are heavy isotopes (with an additional neutron in the nucleus). This liquid is almost indistinguishable from normal water. But here the properties are very different. To perturb the heavy water in the same way, it required a concentration of ions six times higher. Further evidence of the uniqueness of water.

No link with water memory

Roke and her team are aware that it might be tempting to link these stunning results to all sorts of controversial beliefs about water. They are however careful to distance themselves from any far-fetched interpretation. "Our research has nothing to do with water memory or homeopathy," she said. "We collect scientific data, which are all verifiable. "To prove the role of water in homeopathy, another million-billion-billion water molecules would have to be affected to even come close, and even then we are not certain."

The new discovery about the behavior of water will be useful in fundamental research, and in other areas too. The interaction between water and ions is omnipresent in biological processes related to enzymes, ion channels and protein folding. Every new piece of knowledge gives greater insight into how life works. [10]

Photonic molecules

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

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

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

"Most of the properties of light we know about originate from the fact that photons are massless, and that they do not interact with each other," Lukin said. "What we have done is create a special type of medium in which photons interact with each other so strongly that they begin to act as though they have mass, and they bind together to form molecules. This type of photonic bound state has been discussed theoretically for quite a while, but until now it hadn't been observed. [9]

The Electromagnetic Interaction

This paper explains the magnetic effect of the electric current from the observed effects of the accelerating electrons, causing naturally the experienced changes of the electric field potential along the electric wire. The accelerating electrons explain not only the Maxwell Equations and the Special

Relativity, but the Heisenberg Uncertainty Relation, the wave particle duality and the electron's spin also, building the bridge between the Classical and Quantum Theories. [2]

Asymmetry in the interference occurrences of oscillators

The asymmetrical configurations are stable objects of the real physical world, because they cannot annihilate. One of the most obvious asymmetry is the proton – electron mass rate $M_p = 1840\ M_e$ while they have equal charge. We explain this fact by the strong interaction of the proton, but how remember it his strong interaction ability for example in the H – atom where are only electromagnetic interactions among proton and electron.

This gives us the idea to origin the mass of proton from the electromagnetic interactions by the way interference occurrences of oscillators. The uncertainty relation of Heisenberg makes sure that the particles are oscillating.

The resultant intensity due to n equally spaced oscillators, all of equal amplitude but different from one another in phase, either because they are driven differently in phase or because we are looking at them an angle such that there is a difference in time delay:

(1) $I = I_0 \sin^2 n\,\phi/2 \,/\, \sin^2 \phi/2$

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

(2) $I = n^2 I_0$

This gives us the idea of

(3) $M_p = n^2 M_e$

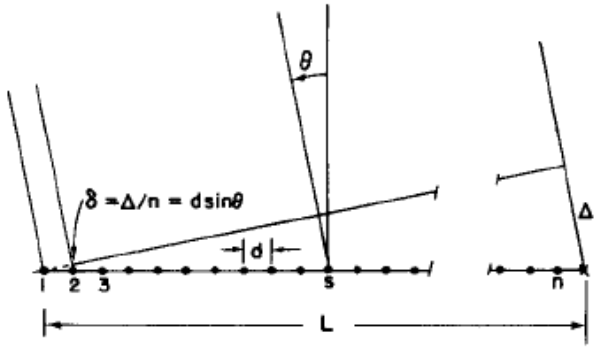

Fig. 30–3. A linear array of n equal oscillators, driven with phases $\alpha_s = s\alpha$.

Figure 1.) A linear array of n equal oscillators

There is an important feature about formula (1) which is that if the angle ϕ is increased by the multiple of 2π, it makes no difference to the formula.

So

(4) $d \sin \theta = m \lambda$

and we get m-order beam if λ less than d. [6]

If d less than λ we get only zero-order one centered at $\theta = 0$. Of course, there is also a beam in the opposite direction. The right chooses of d and λ we can ensure the conservation of charge.

For example

(5) $2 (m+1) = n$

Where $2(m+1) = N_p$ number of protons and $n = N_e$ number of electrons.

In this way we can see the H_2 molecules so that 2n electrons of n radiate to 4(m+1) protons, because $d_e > \lambda_e$ for electrons, while the two protons of one H_2 molecule radiate to two electrons of them, because of $d_e < \lambda_e$ for this two protons.

To support this idea we can turn to the Planck distribution law, that is equal with the Bose – Einstein statistics.

Spontaneously broken symmetry in the Planck distribution law

The Planck distribution law is temperature dependent and it should be true locally and globally. I think that Einstein's energy-matter equivalence means some kind of existence of electromagnetic oscillations enabled by the temperature, creating the different matter formulas, atoms molecules, crystals, dark matter and energy.

Max Planck found for the black body radiation

As a function of wavelength (λ), Planck's law is written as:

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

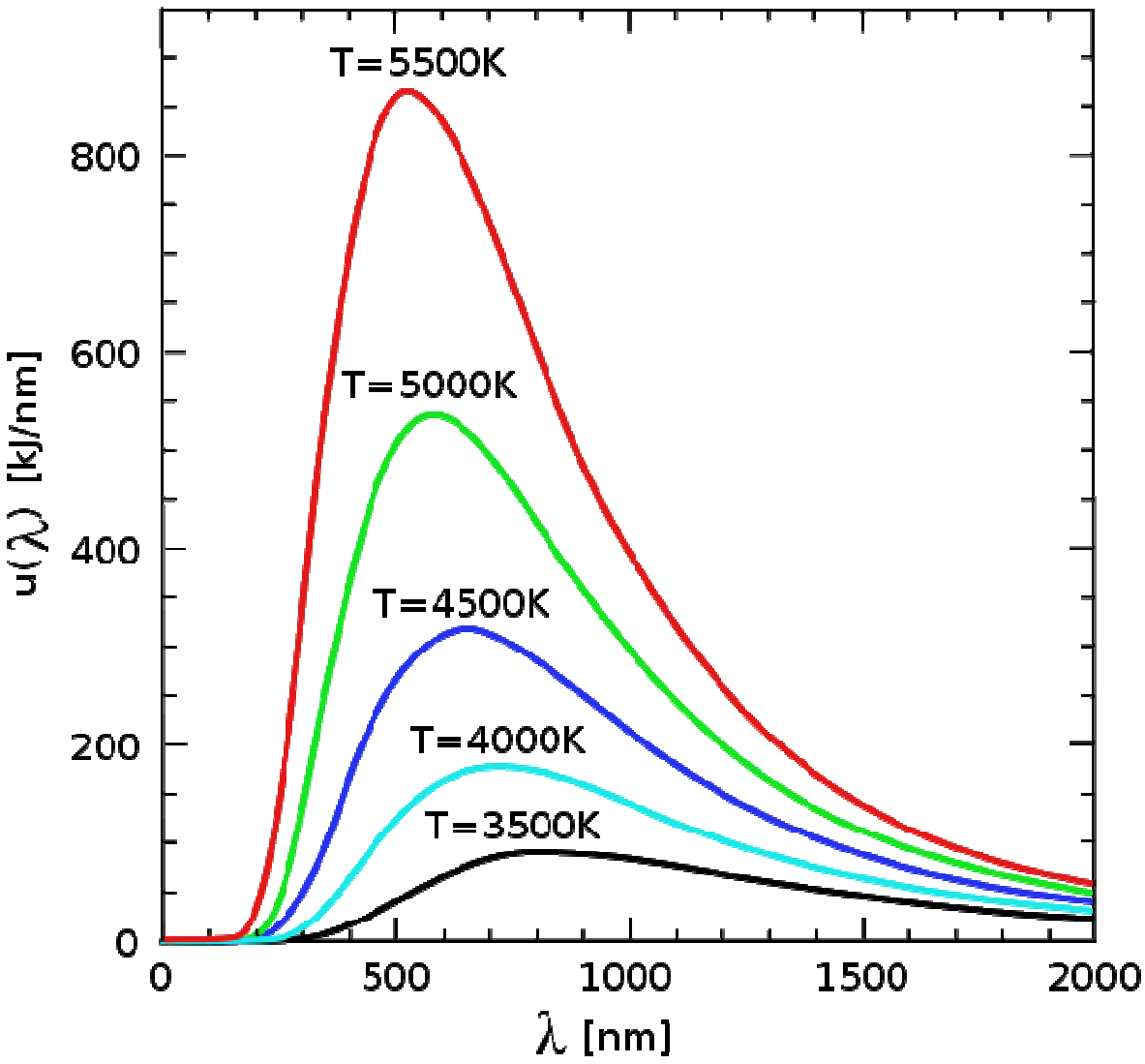

Figure 2. The distribution law for different T temperatures

We see there are two different λ_1 and λ_2 for each T and intensity, so we can find between them a d so that $\lambda_1 < d < \lambda_2$.

We have many possibilities for such asymmetrical reflections, so we have many stable oscillator configurations for any T temperature with equal exchange of intensity by radiation. All of these configurations can exist together. At the λ_{max} is the annihilation point where the configurations are symmetrical. The λ_{max} is changing by the Wien's displacement law in many textbooks.

(7) $$\lambda_{max} = \frac{b}{T}$$

where λ_{max} is the peak wavelength, T is the absolute temperature of the black body, and b is a constant of proportionality called *Wien's displacement constant*, equal to $2.8977685(51)\times10^{-3}$ m·K (2002 CODATA recommended value).

By the changing of T the asymmetrical configurations are changing too.

The structure of the proton

We must move to the higher T temperature if we want look into the nucleus or nucleon arrive to $d<10^{-13}$ cm. If an electron with $\lambda_e < d$ move across the proton then by (5) $2(m+1) = n$ with $m = 0$ we get $n = 2$ so we need two particles with negative and two particles with positive charges. If the proton can fraction to three parts, two with positive and one with negative charges, then the reflection of oscillators are right. Because this very strange reflection where one part of the proton with the electron together on the same side of the reflection, the all parts of the proton must be quasi lepton so $d > \lambda_q$. One way dividing the proton to three parts is, dividing his oscillation by the three direction of the space. We can order 1/3 e charge to each coordinates and 2/3 e charge to one plane oscillation, because the charge is scalar. In this way the proton has two +2/3 e plane oscillation and one linear oscillation with -1/3 e charge. The colors of quarks are coming from the three directions of coordinates and the proton is colorless. The flavors of quarks are the possible oscillations differently by energy and if they are plane or linear oscillations. We know there is no possible reflecting two oscillations to each other which are completely orthogonal, so the quarks never can be free, however there is an asymptotic freedom while their energy are increasing to turn them to the orthogonally. If they will be completely orthogonal then they lose this reflection and take new partners from the vacuum. Keeping the symmetry of the vacuum the new oscillations are keeping all the conservation laws, like charge, number of baryons and leptons. The all features of gluons are coming from this model. The mathematics of reflecting oscillators show Fermi statistics.

Important to mention that in the Deuteron there are 3 quarks of +2/3 and -1/3 charge, that is three u and d quarks making the complete symmetry and because this its high stability.

The Pauli Exclusion Principle says that the diffraction points are exclusive!

The Strong Interaction

Confinement and Asymptotic Freedom

For any theory to provide a successful description of strong interactions it should simultaneously exhibit the phenomena of confinement at large distances and asymptotic freedom at short distances. Lattice calculations support the hypothesis that for non-abelian gauge theories the two domains are analytically connected, and confinement and asymptotic freedom coexist.
Similarly, one way to show that QCD is the correct theory of strong interactions is that the coupling extracted at various scales (using experimental data or lattice simulations) is unique in the sense that its variation with scale is given by the renormalization group. [4]
Lattice QCD gives the same results as the diffraction theory of the electromagnetic oscillators, which is the explanation of the strong force and the quark confinement. [1]

The weak interaction

The weak interaction transforms an electric charge in the diffraction pattern from one side to the other side, causing an electric dipole momentum change, which violates the CP and time reversal symmetry.

Another important issue of the quark model is when one quark changes its flavor such that a linear oscillation transforms into plane oscillation or vice versa, changing the charge value with 1 or -1. This kind of change in the oscillation mode requires not only parity change, but also charge and time changes (CPT symmetry) resulting a right handed anti-neutrino or a left handed neutrino.

The right handed anti-neutrino and the left handed neutrino exist only because changing back the quark flavor could happen only in reverse, because they are different geometrical constructions, the u is 2 dimensional and positively charged and the d is 1 dimensional and negatively charged. It needs also a time reversal, because anti particle (anti neutrino) is involved.

The neutrino is a 1/2spin creator particle to make equal the spins of the weak interaction, for example neutron decay to 2 fermions, every particle is fermions with ½ spin. The weak interaction changes the entropy since more or less particles will give more or less freedom of movement. The entropy change is a result of temperature change and breaks the equality of oscillator diffraction intensity of the Maxwell–Boltzmann statistics. This way it changes the time coordinate measure and makes possible a different time dilation as of the special relativity.

The limit of the velocity of particles as the speed of light appropriate only for electrical charged particles, since the accelerated charges are self maintaining locally the accelerating electric force. The neutrinos are CP symmetry breaking particles compensated by time in the CPT symmetry, that is the time coordinate not works as in the electromagnetic interactions, consequently the speed of neutrinos is not limited by the speed of light.

The weak interaction T-asymmetry is in conjunction with the T-asymmetry of the second law of thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes the weak interaction, for example the Hydrogen fusion.

Probably because it is a spin creating movement changing linear oscillation to 2 dimensional oscillation by changing d to u quark and creating anti neutrino going back in time relative to the proton and electron created from the neutron, it seems that the anti neutrino fastest then the velocity of the photons created also in this weak interaction?

A quark flavor changing shows that it is a reflection changes movement and the CP- and T- symmetry breaking. This flavor changing oscillation could prove that it could be also on higher level such as atoms, molecules, probably big biological significant molecules and responsible on the aging of the life.

Important to mention that the weak interaction is always contains particles and antiparticles, where the neutrinos (antineutrinos) present the opposite side. It means by Feynman's interpretation that these particles present the backward time and probably because this they seem to move faster than the speed of light in the reference frame of the other side.

Finally since the weak interaction is an electric dipole change with ½ spin creating; it is limited by the velocity of the electromagnetic wave, so the neutrino's velocity cannot exceed the velocity of light.

The General Weak Interaction

The Weak Interactions T-asymmetry is in conjunction with the T-asymmetry of the Second Law of

Thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes for example the Hydrogen fusion. The arrow of time by the Second Law of Thermodynamics shows the increasing entropy and decreasing information by the Weak Interaction, changing the temperature dependent diffraction patterns. A good example of this is the neutron decay, creating more particles with less known information about them.

The neutrino oscillation of the Weak Interaction shows that it is a general electric dipole change and it is possible to any other temperature dependent entropy and information changing diffraction pattern of atoms, molecules and even complicated biological living structures.

We can generalize the weak interaction on all of the decaying matter constructions, even on the biological too. This gives the limited lifetime for the biological constructions also by the arrow of time. There should be a new research space of the Quantum Information Science the 'general neutrino oscillation' for the greater then subatomic matter structures as an electric dipole change.

There is also connection between statistical physics and evolutionary biology, since the arrow of time is working in the biological evolution also.

The Fluctuation Theorem says that there is a probability that entropy will flow in a direction opposite to that dictated by the Second Law of Thermodynamics. In this case the Information is growing that is the matter formulas are emerging from the chaos. So the Weak Interaction has two directions, samples for one direction is the Neutron decay, and Hydrogen fusion is the opposite direction. [5]

Fermions and Bosons

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

The Higgs boson or Higgs particle is a proposed elementary particle in the Standard Model of particle physics. The Higgs boson's existence would have profound importance in particle physics because it would prove the existence of the hypothetical Higgs field - the simplest of several proposed explanations for the origin of the symmetry-breaking mechanism by which elementary particles gain mass. [3]

The fermions' spin

The moving charges are accelerating, since only this way can self maintain the electric field causing their acceleration. The electric charge is not point like! This constant acceleration possible if there is

a rotating movement changing the direction of the velocity. This way it can accelerate forever without increasing the absolute value of the velocity in the dimension of the time and not reaching the velocity of the light.

The Heisenberg uncertainty relation says that the minimum uncertainty is the value of the spin: 1/2 h = d x d p or 1/2 h = d t d E, that is the value of the basic energy status.

What are the consequences of this in the weak interaction and how possible that the neutrinos' velocity greater than the speed of light?

The neutrino is the one and only particle doesn't participate in the electromagnetic interactions so we cannot expect that the velocity of the electromagnetic wave will give it any kind of limit.

The neutrino is a 1/2spin creator particle to make equal the spins of the weak interaction, for example neutron decay to 2 fermions, every particle is fermions with ½ spin. The weak interaction changes the entropy since more or less particles will give more or less freedom of movement. The entropy change is a result of temperature change and breaks the equality of oscillator diffraction intensity of the Maxwell–Boltzmann statistics. This way it changes the time coordinate measure and makes possible a different time dilation as of the special relativity.

The source of the Maxwell equations

The electrons are accelerating also in a static electric current because of the electric force, caused by the potential difference. The magnetic field is the result of this acceleration, as you can see in [2].

The mysterious property of the matter that the electric potential difference is self maintained by the accelerating electrons in the electric current gives a clear explanation to the basic sentence of the relativity that is the velocity of the light is the maximum velocity of the matter. If the charge could move faster than the electromagnetic field than this self maintaining electromagnetic property of the electric current would be failed.

Also an interesting question, how the changing magnetic field creates a negative electric field?
The answer also the accelerating electrons will give. When the magnetic field is increasing in time by increasing the electric current, then the acceleration of the electrons will increase, decreasing the charge density and creating a negative electric force. Decreasing the magnetic field by decreasing the electric current will decrease the acceleration of the electrons in the electric current and increases the charge density, creating an electric force also working against the change.
In this way we have explanation to all interactions between the electric and magnetic forces described in the Maxwell equations.
The second mystery of the matter is the mass. We have seen that the acceleration change of the electrons in the flowing current causing a negative electrostatic force. This is the cause of the relativistic effect - built-in in the Maxwell equations - that is the mass of the electron growing with its acceleration and its velocity never can reach the velocity of light, because of this growing negative electrostatic force. The velocity of light is depending only on 2 parameters: the magnetic permeability and the electric permittivity.
There is a possibility of the polarization effect created by electromagnetic forces creates the negative and positive charges. In case of equal mass as in the electron-positron pair it is simply, but

on higher energies can be asymmetric as the electron-proton pair of neutron decay by week interaction and can be understood by the Feynman graphs.
Anyway the mass can be electromagnetic energy exceptionally and since the inertial and gravitational mass are equals, the gravitational force is electromagnetic force and since only the magnetic force is attractive between the same charges, is very important for understanding the gravitational force.

The Uncertainty Relations of Heisenberg gives the answer, since only this way can be sure that the particles are oscillating in some way by the electromagnetic field with constant energies in the atom indefinitely. Also not by chance that the uncertainty measure is equal to the fermions spin, which is one of the most important feature of the particles. There are no singularities, because the moving electron in the atom accelerating in the electric field of the proton, causing a charge distribution on delta x position difference and with a delta p momentum difference such a way that they product is about the half Planck reduced constant. For the proton this delta x much less in the nucleon, than in the orbit of the electron in the atom, the delta p is much higher because of the greatest proton mass.

The Special Relativity

The mysterious property of the matter that the electric potential difference is self maintained by the accelerating electrons in the electric current gives a clear explanation to the basic sentence of the relativity that is the velocity of the light is the maximum velocity of the matter. If the charge could move faster than the electromagnetic field than this self maintaining electromagnetic property of the electric current would be failed. [8]

The Heisenberg Uncertainty Principle

Moving faster needs stronger acceleration reducing the dx and raising the dp. It means also mass increasing since the negative effect of the magnetic induction, also a relativistic effect!

The Uncertainty Principle also explains the proton – electron mass rate since the dx is much less requiring bigger dp in the case of the proton, which is partly the result of a bigger mass m_p because of the higher electromagnetic induction of the bigger frequency (impulse).

The Gravitational force

The changing magnetic field of the changing current causes electromagnetic mass change by the negative electric field caused by the changing acceleration of the electric charge.

The gravitational attractive force is basically a magnetic force.

The same electric charges can attract one another by the magnetic force if they are moving parallel in the same direction. Since the electrically neutral matter is composed of negative and positive charges they need 2 photons to mediate this attractive force, one per charges. The Bing Bang caused parallel moving of the matter gives this magnetic force, experienced as gravitational force.

Since graviton is a tensor field, it has spin = 2, could be 2 photons with spin = 1 together.

You can think about photons as virtual electron – positron pairs, obtaining the necessary virtual mass for gravity.

The mass as seen before a result of the diffraction, for example the proton – electron mass rate M_p = 1840 M_e. In order to move one of these diffraction maximum (electron or proton) we need to intervene into the diffraction pattern with a force appropriate to the intensity of this diffraction maximum, means its intensity or mass. [1]

The Big Bang caused acceleration created radial currents of the matter, and since the matter is composed of negative and positive charges, these currents are creating magnetic field and attracting forces between the parallel moving electric currents. This is the gravitational force experienced by the matter, and also the mass is result of the electromagnetic forces between the charged particles. The positive and negative charged currents attracts each other or by the magnetic forces or by the much stronger electrostatic forces!?

The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.
There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

The Graviton

In physics, the graviton is a hypothetical elementary particle that mediates the force of gravitation in the framework of quantum field theory. If it exists, the graviton is expected to be massless (because the gravitational force appears to have unlimited range) and must be a spin-2 boson. The spin follows from the fact that the source of gravitation is the stress-energy tensor, a second-rank tensor (compared to electromagnetism's spin-1 photon, the source of which is the four-current, a first-rank tensor). Additionally, it can be shown that any massless spin-2 field would give rise to a force indistinguishable from gravitation, because a massless spin-2 field must couple to (interact with) the stress-energy tensor in the same way that the gravitational field does. This result suggests that, if a massless spin-2 particle is discovered, it must be the graviton, so that the only experimental verification needed for the graviton may simply be the discovery of a massless spin-2 particle. [3]

What is the Spin?

So we know already that the new particle has spin zero or spin two and we could tell which one if we could detect the polarizations of the photons produced. Unfortunately this is difficult and neither ATLAS nor CMS are able to measure polarizations. The only direct and sure way to confirm that the particle is indeed a scalar is to plot the angular distribution of the photons in the rest frame of the centre of mass. A spin zero particles like the Higgs carries no directional information away from the original collision so the distribution will be even in all directions. This test will be possible when a much larger number of events have been observed. In the mean time we can settle for less certain indirect indicators.

The Casimir effect

The Casimir effect is related to the Zero-point energy, which is fundamentally related to the Heisenberg uncertainty relation. The Heisenberg uncertainty relation says that the minimum uncertainty is the value of the spin: 1/2 h = dx dp or 1/2 h = dt dE, that is the value of the basic energy status.
The moving charges are accelerating, since only this way can self maintain the electric field causing their acceleration. The electric charge is not point like! This constant acceleration possible if there is a rotating movement changing the direction of the velocity. This way it can accelerate forever without increasing the absolute value of the velocity in the dimension of the time and not reaching the velocity of the light. In the atomic scale the Heisenberg uncertainty relation gives the same result, since the moving electron in the atom accelerating in the electric field of the proton, causing a charge distribution on delta x position difference and with a delta p momentum difference such a way that they product is about the half Planck reduced constant. For the proton this delta x much less in the nucleon, than in the orbit of the electron in the atom, the delta p is much higher because of the greater proton mass. This means that the electron is not a point like particle, but has a real charge distribution.
Electric charge and electromagnetic waves are two sides of the same thing; the electric charge is the diffraction center of the electromagnetic waves, quantified by the Planck constant h.

The Fine structure constant

The Planck constant was first described as the proportionality constant between the energy (E) of a photon and the frequency (ν) of its associated electromagnetic wave. This relation between the energy and frequency is called the **Planck relation** or the **Planck–Einstein equation**:

$$E = h\nu\,.$$

Since the frequency ν, wavelength λ, and speed of light c are related by $\lambda\nu = c$, the Planck relation can also be expressed as

$$E = \frac{hc}{\lambda}.$$

Since this is the source of Planck constant, the e electric charge countable from the Fine structure constant. This also related to the Heisenberg uncertainty relation, saying that the mass of the proton should be bigger than the electron mass because of the difference between their wavelengths.

The expression of the fine-structure constant becomes the abbreviated

$$\alpha = \frac{e^2}{\hbar c}$$

This is a dimensionless constant expression, 1/137 commonly appearing in physics literature.

This means that the electric charge is a result of the electromagnetic waves diffractions, consequently the proton – electron mass rate is the result of the equal intensity of the corresponding electromagnetic frequencies in the Planck distribution law, described in my diffraction theory.

Path integral formulation of Quantum Mechanics

The path integral formulation of quantum mechanics is a description of quantum theory which generalizes the action principle of classical mechanics. It replaces the classical notion of a single, unique trajectory for a system with a sum, or functional integral, over an infinity of possible trajectories to compute a quantum amplitude. [7]

It shows that the particles are diffraction patterns of the electromagnetic waves.

Conclusions

"It's a photonic interaction that's mediated by the atomic interaction," Lukin said. "That makes these two photons behave like a molecule, and when they exit the medium they're much more likely to do so together than as single photons." To build a quantum computer, he explained, researchers need to build a system that can preserve quantum information, and process it using quantum logic operations. The challenge, however, is that quantum logic requires interactions between individual quanta so that quantum systems can be switched to perform information processing. [9]

The magnetic induction creates a negative electric field, causing an electromagnetic inertia responsible for the relativistic mass change; it is the mysterious Higgs Field giving mass to the particles. The Planck Distribution Law of the electromagnetic oscillators explains the electron/proton mass rate by the diffraction patterns. The accelerating charges explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the wave particle duality and the electron's spin also, building the bridge between the Classical and Relativistic Quantum Theories. The self maintained electric potential of the accelerating charges equivalent with

the General Relativity space-time curvature, and since it is true on the quantum level also, gives the base of the Quantum Gravity. The electric currents causing self maintaining electric potential is the source of the special and general relativistic effects. The Higgs Field is the result of the electromagnetic induction. The Graviton is two photons together.

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