Acoustic Atoms

Yale scientists have shown how to enhance the lifetime of sound waves traveling through glass—the material at the heart of fiber optic technologies. [16]

Electron microscopy of a manganese dioxide nanowire in cross-section shows its tunnelled atomic structure, stabilized by potassium ions. [15]

Physicists of the University of Würzburg have made an astonishing discovery in a specific type of topological insulators. [14]

Materials scientists at Caltech have discovered a new way that heat tweaks the physical properties of a material. [13]

That is, until now, thanks to the new solution devised at TU Wien: for the first time ever, permanent magnets can be produced using a 3D printer. This allows magnets to be produced in complex forms and precisely customised magnetic fields, required, for example, in magnetic sensors. [12]

For physicists, loss of magnetisation in permanent magnets can be a real concern. In response, the Japanese company Sumitomo created the strongest available magnet—one offering ten times more magnetic energy than previous versions—in 1983. [11]

New method of superstrong magnetic fields' generation proposed by Russian scientists in collaboration with foreign colleagues. [10]

By showing that a phenomenon dubbed the "inverse spin Hall effect" works in several organic semiconductors - including carbon-60 buckyballs - University of Utah physicists changed magnetic "spin current" into electric current. The efficiency of this new power conversion method isn't yet known, but it might find use in future electronic devices including batteries, solar cells and computers. [9]

Researchers from the Norwegian University of Science and Technology (NTNU) and the University of Cambridge in the UK have demonstrated that it is possible to directly generate an electric current in a magnetic material by rotating its magnetization. [8]

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.*

The changing acceleration of the electrons explains the created negative electric field of the magnetic induction, the changing relativistic mass and the Gravitational Force, giving a Unified Theory of the physical forces. Taking into account the Planck Distribution Law of the electromagnetic oscillators also, we can explain the electron/proton mass rate and the Weak and Strong Interactions.

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Author: George Rajna

Preface

Surprisingly nobody found strange that by theory the electrons are moving with a constant velocity in the stationary electric current, although there is an accelerating force **F = q E**, imposed by the **E** electric field along the wire as a result of the **U** potential difference. The accelerated electrons are creating a charge density distribution and maintaining the potential change along the wire. This charge distribution also creates a radial electrostatic field around the wire decreasing along the wire. The moving external electrons in this electrostatic field are experiencing a changing electrostatic field causing exactly the magnetic effect, repelling when moving against the direction of the current and attracting when moving in the direction of the current. This way the **A** magnetic potential is based on the real charge distribution of the electrons caused by their acceleration, maintaining the **E** electric field and the **A** magnetic potential at the same time.

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 electromagnetic matter. If the charge could move faster than the electromagnetic field, this self maintaining electromagnetic property of the electric current would be failed.

More importantly the accelerating electrons can explain the magnetic induction also. The changing acceleration of the electrons will create a –**E** electric field by changing the charge distribution, increasing acceleration lowering the charge density and decreasing acceleration causing an increasing charge density.

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as a relativistic changing electromagnetic mass. If the mass is electromagnetic, then the gravitation is also electromagnetic effect. The same charges would attract each other if they are moving parallel by the magnetic effect.

Tapping into long-lived sound waves in glass

Yale scientists have shown how to enhance the lifetime of sound waves traveling through glass—the material at the heart of fiber optic technologies. The discovery will be described in the January edition of the journal Nature Materials.

Everyday experience tells us that glass (silica) is highly transparent. In fact, silica is one of the most transparent materials on earth. Light can propagate for tens of kilometers in silica before it experiences any appreciable weakening. This transparency, combined with glass' formability and low cost, is why glass is used in so many of the fiber-optic technologies that shape the information age.

Yet silica also has a mysterious side. At room temperature, silica is an excellent acoustic material. You can demonstrate this by tapping a wine glass with a fork and listening to it ring for several seconds. However, in sharp contrast with most materials, this resonance is quickly muted when the glass is cooled to cryogenic temperatures.

These peculiar acoustic properties are at the heart of long-standing mysteries in glass physics. In the 1960s scientists discovered many perplexing properties of glass: It conducted heat much less efficiently than expected, and it heated up much more slowly than anticipated. These puzzling discoveries were ultimately explained by localized absorbers within glass that interact with sound waves in the same manner that atoms interact with light. To this day however, the true nature of these "acoustic atoms" is not fully understood.

In addition, absorption by these "acoustic atoms" has another consequence that intrigues scientists. At low temperatures the amplitude of a sound wave affects how long it will ring. Roughly speaking, this means you can make your wine glass ring longer by turning on your stereo, which causes the glass to vibrate at altogether different frequencies. Moreover, the duration of the ringing increases as the stereo volume is turned up.

Yale scientists have used this concept to control the lifetime of sound within glass. By shining laser light into fiber optic waveguides made of glass, they were able to probe and generate acoustic waves in the fiber core. By generating an intense acoustic wave at one frequency (i.e. "turning on the stereo") and probing at another ("tapping a wine glass"), the researchers were able to extend the lifetime of a sound wave.

The researchers said that because glass is the backbone of a range of cutting-edge technologies, the findings open the possibility of new forms of high-precision sensing and information processing.

"Our work takes an important step toward engineered sound dynamics in glass," said Peter Rakich, assistant professor of applied physics and physics at Yale and principal investigator of the study. [16]

Researchers peer into atom-sized tunnels in hunt for better battery

Battery researchers seeking improved electrode materials have focused on "tunneled" structures that make it easier for charge-carrying ions to move in and out of the electrode. Now a team led by a researcher at the University of Illinois at Chicago has used a special electron microscope with atomic-level resolution to show that certain large ions can hold the tunnels open so that the charge-carrying ions can enter and exit the electrode easily and quickly.

The finding is reported in Nature Communications.

"Significant research has been done to increase the energy density and power density of lithium ion battery systems," says Reza Shahbazian-Yassar, associate professor of mechanical and industrial engineering at UIC.

The current generation, he said, is useful enough for portable devices, but the maximum energy and power that can be extracted is limiting.

"So for an electric car, we need to increase the energy and power of the battery—and decrease the cost as well," he said.

His team, which includes coworkers at Argonne National Laboratory, Michigan Technological Institute and the University of Bath in the U.K., has focused on developing a cathode based on manganese dioxide, a very low cost and environmentally-friendly material with high storage capacity.

Manganese dioxide has a lattice structure with regularly spaced tunnels that allow charge carriers—like lithium ions—to move in and out freely.

"But for the tunnels to survive for long-lasting function, they need support structures at the atomic scale," Shahbazian-Yassar said. "We call them tunnel stabilizers, and they are generally big, positive ions, like potassium or barium."

But the tunnel stabilizers, being positively charged like the lithium ions, should repel each other.

"If lithium goes in, will the tunnel stabilizer come out?" Shahbazian-Yassar shrugged. "The research community was in disagreement about the role of tunnel stabilizers during the transfer of lithium into tunnels. Does it help, or hurt?"

The new study represents the first use of electron microscopy to visualize the atomic structure of tunnels in a one-dimensional electrode material—which the researchers say had not previously been possible due to the difficulty of preparing samples. It took them two years to establish the procedure to look for tunnels in potassium-doped nanowires of manganese dioxide down to the single-atom level.

Yifei Yuan, a postdoctoral researcher working jointly at Argonne National Laboratory and UIC and the lead author on the study, was then able to use a powerful technique called aberration-corrected scanning transmission electron microscopy to image the tunnels at sub-ångstrom resolution so he could clearly see inside them—and he saw they do change in the presence of a stabilizer ion.

"It's a direct way to see the tunnels," Yuan said. "And we saw that when you add a tunnel stabilizer, the tunnels expand, their electronic structures also change, and such changes allow the lithium ions to move in and out, around the stabilizer."

The finding shows that tunnel stabilizers can help in the transfer of ions into tunnels and the rate of charge and discharge, Shahbazian-Yassar said. The presence of potassium ions in the tunnels improves the electronic conductivity of manganese dioxide and the ability of lithium ions to diffuse quickly in and out of the nanowires.

"With potassium ions staying in the center of the tunnels, the capacity retention improves by half under high cycling current, which means the battery can hold on to its capacity for a longer time," he said. [15]

Electron highway inside crystal

Physicists of the University of Würzburg have made an astonishing discovery in a specific type of topological insulators. The effect is due to the structure of the materials used. The researchers have now published their work in the journal Science.

Topological insulators are currently the hot topic in physics according to the newspaper Neue Zürcher Zeitung. Only a few weeks ago, their importance was highlighted again as the Royal Swedish Academy of Sciences in Stockholm awarded this year's Nobel Prize in Physics to three British scientists for their research of so-called topological phase transitions and topological phases of matter.

Topological insulators are also being studied at the Departments for Experimental Physics II and Theoretical Physics I of the University of Würzburg. However, they focus on a special version of insulators called topological crystalline insulators (TCI). In cooperation with the Polish Academy of Sciences in Warsaw and the University of Zurich, Würzburg physicists have now achieved a major breakthrough. They were able to detect new electronic states of matter in these insulators. The results of their work are published in the latest issue of Science.

Step edges direct electrons

The central result: When crystalline materials are split, small atomically flat terraces emerge at the split off surfaces which are separated from each other by step edges. Inside these structures, conductive channels for electrical currents form which are extremely narrow at just about 10 nm and surprisingly robust against external disturbance. Electrons travel on these conductive channels with different spin in opposite directions - similar to a motorway with separate lanes for the two directions. This effect makes the materials interesting for technological applications in future electronic components such as ultra-fast and energy-efficient computers.

"TCIs are relatively simple to produce and they are already different from conventional materials because of their special crystalline structure," Dr. Paolo Sessi explains the background of the recently published paper. Sessi is a research fellow at the Department of Experimental Physics II and the lead author of the study. Moreover, these materials owe their special quality to their electronic properties: In topological materials, the direction of spin determines the direction in which the electrons travel. Simply put, the "spin" can be interpreted as a magnetic dipole that can point in two directions ("up" and "down"). Accordingly, up-spin electrons in TCIs move in one and down-spin electrons in the other direction.

It's all about the number of atomic layers

"But previously scientists didn't know how to produce the conductive channels required to this end," says Professor Matthias Bode, Head of the Department for Experimental Physics II and co-author of the study. It was chance that now got the researchers on the right track: They discovered that very narrow conductive channels occur naturally when splitting lead tin selenide (PbSnSe), a crystalline insulator.

Step edges on the fragments' surfaces cause this phenomenon. They can be imaged using a high-resolution scanning tunnelling microscopy, or more precisely, the height of the corresponding step edges. "Edges that bridge an even number of atomic layers are totally inconspicuous. But if the edges span an odd number of atomic layers, a small area about 10 nm in width is created that has the electronic conductive channels properties we were looking for," Sessi explains.

Pattern breaks off at the edge

Supported by their colleagues from the Department of Theoretical Physics I and the University of Zurich, the experimental physicists were able to shed light on the origin of these new electronic states. To understand the principle, a little spatial sense is required:

"The crystalline structure causes a layout of the atoms where the different elements alternate like the black and white squares on a chessboard," Matthias Bode explains. This alternating black-and-white pattern applies to both squares which are adjacent and squares situated below and on top one another.

So if the crack of this crystal runs through different atomic layers, more than one edge is created there. Seen from above, white squares may also abut to other white squares along this edge and black squares to other black squares - or identical atoms to identical atoms. However, this only works if an odd number of atomic layers is responsible for the difference in height of the two surfaces.

Backed by calculations

"Calculations show that this offset at the surface is actually causative of these novel electronic states," says Paolo Sessi. Furthermore, they prove that the phenomenon of the spin-dependent conductive channels, which is characteristic of topological materials, occurs here as well.

According to the scientists, this property in particular makes the discovery relevant for potential applications, because such conductive channels cause low conduction loss on the one hand and can be used directly to transmit and process information in the field of spintronics on the other.

However, several questions need to be answered and challenges to be overcome before this will become reality. For instance, the scientists are not yet sure over which distances the currents in the newly discovered conductive channels can be transported. Also, in order to be implemented in circuits, methods would have to be developed that allow creating step edges of a defined height along specified directions. [14]

Raising temperature changes an element's electronic 'topology'

Materials scientists at Caltech have discovered a new way that heat tweaks the physical properties of a material.

Experimenting with an alloy of iron and titanium (FeTi), a team led by Caltech's Brent Fultz found that increasing heat alters the topology of the material's Fermi surface—an abstract map of the allowable energy states that can be occupied by electrons.

Fultz, the Barbara and Stanley R. Rawn, Jr., Professor of Materials Science and Applied Physics in the Division of Engineering and Applied Science, likens a Fermi surface to a planet covered by a smooth ocean and rocky landmasses. The ocean is made up of electrons, while the land represents voids where electrons are not present. Placing an element under extreme pressure—like that in Earth's core—can cause landforms lurking just below the surface to emerge, in turn altering where electrons are likely to be found. The appearance of these new features in a Fermi surface is called an electronic topological transition (ETT). The concept of an ETT was proposed by the Russian physicist I. M. Lifshitz in 1960, and ETTs have been observed by subjecting metals to pressures on the order of 100,000 atmospheres.

Heating causes electrons to slosh around within the Fermi surface, but, as with waves moving on water, the coastlines—the boundaries between electrons and electron-less voids—remain about the same. However, Fultz and his colleagues noticed that because heat also displaces atoms, heating can in some cases reveal landforms hidden below the surface of that metaphorical Fermi sea.

In practical terms, altering the topology of the Fermi surface alters the chemical properties of a metal or alloy, which in turn alters its electrical conductivity.

The potential value to engineers lies in the fact that it is much easier to raise the temperature of a material than it is to place it under the sort of pressure needed to force an ETT. "The pressures needed to cause an ETT are intense, while the temperature changes needed are comparatively low," says Fultz. Indeed, gigapascals of pressure are required to cause an ETT—that is, tens of thousands of times the pressure of Earth's atmosphere. However, Fultz and his colleagues noted ETTs occurring within hundreds of degrees Fahrenheit of temperature change.

The discovery was something of an accident—the result of computationally chasing down anomalous results while performing neutron scattering tests on an FeTi alloy that is of interest to engineers because it is remarkably strong and stretchable.

Neutron scattering reveals details about a material's atomic structure. In the method, a beam of neutrons is fired at a material and the energies and angles of the scattered neutrons are recorded and analyzed. In particular, Fultz's group was using neutron scattering to study the vibrations of atoms in crystals, which almost always move and buzz slightly. The researchers found that, with increasing temperatures, the specific patterns of buzzing changed dramatically in a way that could not be explained through known mechanisms.

Caltech graduate student Fred Yang (MS '15), lead author of a paper about the discovery appearing in the journal Physical Review Letters, ran numerous computer simulations that suggested the temperature-related change could be explained by an ETT in FeTi.

Next, Fultz and Yang plan to explore other elements with features lurking just below their Fermi surfaces. [13]

For the first time, magnets are be made with a 3-D printer

Today, manufacturing strong magnets is no problem from a technical perspective. It is, however, difficult to produce a permanent magnet with a magnetic field of a specific pre-determined shape. That is, until now, thanks to the new solution devised at TU Wien: for the first time ever, permanent magnets can be produced using a 3D printer. This allows magnets to be produced in complex forms and precisely customised magnetic fields, required, for example, in magnetic sensors.

Designed on a computer

"The strength of a magnetic field is not the only factor," says Dieter Süss, Head of the Christian-Doppler Advanced Magnetic Sensing and Materials laboratory at TU Wien. "We often require special magnetic fields, with field lines arranged in a very specific way - such as a magnetic field that is relatively constant in one direction, but which varies in strength in another direction."

In order to achieve such requirements, magnets must be produced with a sophisticated geometric form. "A magnet can be designed on a computer, adjusting its shape until all requirements for its magnetic field are met," explains Christian Huber, a doctoral student in Dieter Süss' team.

But once you have the desired geometric shape, how do you go about implementing the design? The injection moulding process is one solution, but this requires the creation of a mould, which is time-consuming and expensive, rendering this method barely worthwhile for producing small quantities.

Tiny magnetic particles in the polymer matrix

Now, there is a much simpler method: the first-ever 3D printer which can be used to produce magnetic materials, created at TU Wien. 3D printers which generate plastic structures have existed for some time, and the magnet printer functions in much the same way. The difference is that the magnet printer uses specially produced filaments of magnetic micro granulate, which is held together by a polymer binding material. The printer heats the material and applies it point by point in the desired locations using a nozzle. The result is a three-dimensional object composed of roughly 90% magnetic material and 10% plastic.

The end product is not yet magnetic, however, because the granulate is deployed in an unmagnetised state. At the very end of the process, the finished article is exposed to a strong external magnetic field, converting it into a permanent magnet.

"This method allows us to process various magnetic materials, such as the exceptionally strong neodymium iron boron magnets," explains Dieter Süss. "Magnet designs created using a computer can now be quickly and precisely implemented - at a size ranging from just a few centimetres through to decimetres, with an accuracy of well under a single millimetre."

A whole world of new possibilities

Not only is this new process fast and cost-effective, it also opens up new possibilities which would be inconceivable with other techniques: you can use different materials within a single magnet to create a smooth transition between strong and weak magnetism, for instance. "Now we will test the limits of how far we can go - but for now it is certain that 3D printing brings something to magnet design which we could previously only dream of," declares Dieter Süss. [12]

New method to make permanent magnets more stable over time

For physicists, loss of magnetisation in permanent magnets can be a real concern. In response, the Japanese company Sumitomo created the strongest available magnet—one offering ten times more magnetic energy than previous versions—in 1983. These magnets are a combination of materials including rare-earth metal and so-called transition metals, and are accordingly referred to as RE-TM-B magnets. A Russian team has now been pushing the boundaries of magnet design, as published in a recent study in EPJ Plus.

They have developed methods to counter the spontaneous loss of magnetisation, based on their understanding of the underlying physical phenomenon. Roman Morgunov from the Institute of Problems of Chemical Physics at the Russian Academy of Sciences and colleagues have now developed a simple additive-based method for ensuring the stability of permanent magnets over time, with no loss to their main magnetic characteristics.

To design magnets that retain their magnetic stability, the authors altered the chemical composition of a RE-TM-B magnet. Their method consists in inserting small amounts of Samarium atoms at random places within the crystalline sub-lattice of the magnet's rare-earth component. They observed a multi-fold increase in the magnet's stability over time with as little as 1% Samarium. The advantage of using such low quantity of additives to stabilise the magnet is that it does not alter the magnetic properties.

The authors believe this result is linked to Samarium's symmetry. It differs from the crystalline structure of Dysprosium atoms, which enter the composition of the magnet's rare-earth component. As a result, spontaneous magnetisation no longer takes place. This is because the potential barriers separating the magnetisation states of different energies are enhanced by the disrupted symmetry.

Further developments of this research will most likely focus on identifying the discrete magnetisation jumps—elementary events that initiate the reversible magnetisation, leading to a loss in stability. [11]

New method for generating superstrong magnetic fields

Researchers of MEPhI (Russia), the University of Rostock (Germany) and the University of Pisa (Italy) suggest a new method for generating extremely strong magnetic fields of several giga-Gauss in the lab. Currently available techniques produce fields of one order of magnitude less than the new method. In nature, such superstrong fields exist only in the space. Therefore, generation of such fields in laboratory conditions provides new opportunities for the modeling of astrophysical processes. The results will contribute to the new research field of laboratory astrophysics.

The Faraday effect has been known for a long time. It refers to the polarization plane of an electromagnetic wave propagating through a non-magnetic medium, which is rotating in the presence of a constant magnetic field. There is also an inverse process of the generation of a magnetic field during the propagation of a circularly polarized wave through a crystal or plasma. It was considered theoretically in the 1960s by Soviet theorist Lew Pitaevsky, a famous representative of Landau's school. The stronger the wave, the higher the magnetic field it can generate when propagating through a medium. However, a peculiarity of the effect is that it requires absorption for its very existence—it does not occur in entirely transparent media. In highly intense electromagnetic fields, electrons become ultrarelativistic, which considerably reduces their collisions, suppressing conventional absorption. The researchers demonstrate that at very high laser wave intensities, the absorption can be effectively provided by radiation friction instead of binary collisions. This specific friction leads to the generation of a superstrong magnetic field.

According to physicist Sergey Popruzhenko, it will be possible to check the calculations in the near future. Several new laser facilities of record power will be completed in the next several years. Three such lasers are now under construction within the European project Extreme Light Infrastructure (ELI) in the Czech Republic, Romania and Hungary. The Exawatt Center for Extreme Light Studies – XCELS is under the development at the Applied Physics Institute RAS at Nizhny Novgorod. These laser facilities will be capable of the intensities required for the generation of superstrong magnetic fields due to radiation friction and also for the observation of many other fundamental strong-field effects. [10]

Inverse spin Hall effect: A new way to get electricity from magnetism

By showing that a phenomenon dubbed the "inverse spin Hall effect" works in several organic semiconductors - including carbon-60 buckyballs - University of Utah physicists changed magnetic "spin current" into electric current. The efficiency of this new power conversion method isn't yet known, but it might find use in future electronic devices including batteries, solar cells and computers.

"This paper is the first to demonstrate the inverse spin Hall effect in a range of organic semiconductors with unprecedented sensitivity," although a 2013 study by other researchers demonstrated it with less sensitivity in one such material, says Christoph Boehme, a senior author of the study published April 18 in the journal Nature Materials.

"The inverse spin Hall effect is a remarkable phenomenon that turns so-called spin current into an electric current. The effect is so odd that nobody really knows what this will be used for eventually, but many technical applications are conceivable, including very odd new power-conversion schemes," says Boehme, a physics professor.

His fellow senior author, distinguished professor Z. Valy Vardeny, says that by using pulses of microwaves, the inverse spin Hall effect and organic semiconductors to convert spin current into electricity, this new electromotive force generates electrical current in a way different than existing sources.

Coal, gas, hydroelectric, wind and nuclear plants all use dynamos to convert mechanical force into magnetic-field changes and then electricity. Chemical reactions power modern batteries and solar cells convert light to electrical current. Converting spin current into electrical current is another method.

Scientists already are developing such devices, such as a thermoelectric generator, using traditional inorganic semiconductors. Vardeny says organic semiconductors are promising because they are cheap, easily processed and environmentally friendly. He notes that both organic solar cells and organic LED (light-emitting diode) TV displays were developed even though silicon solar cells and nonorganic LEDs were widely used.

A new way to get electricity from magnetism

Vardeny and Boehme stressed that the efficiency at which organic semiconductors convert spin current to electric current remains unknown, so it is too early to predict the extent to which it might one day be used for new power conversion techniques in batteries, solar cells, computers, phones and other consumer electronics.

"I want to invoke a degree of caution," Boehme says. "This is a power conversion effect that is new and mostly unstudied."

Boehme notes that the experiments in the new study converted more spin current to electrical current than in the 2013 study, but Vardeny cautioned the effect still "would have to be scaled up many times to produce voltages equivalent to household batteries."

The new study was funded by the National Science Foundation and the University of Utah-NSF Materials Research Science and Engineering Center. Study co-authors with Vardeny and Boehme were these University of Utah physicists: research assistant professors Dali Sun and Hans Malissa, postdoctoral researchers Kipp van Schooten and Chuang Zhang, and graduate students Marzieh Kavand and Matthew Groesbeck.

From spin current to electric current

Just as atomic nuclei and the electrons that orbit them carry electrical charges, they also have another inherent property: spin, which makes them behave like tiny bar magnets that can point north or south.

Electronic devices store and transmit information using the flow of electricity in the form of electrons, which are negatively charged subatomic particles. The zeroes and ones of computer binary code are represented by the absence or presence of electrons within silicon or other nonorganic semiconductors.

Spin electronics - spintronics - holds promise for faster, cheaper computers, better electronics and LEDs for displays, and smaller sensors to detect everything from radiation to magnetic fields.

The inverse spin Hall effect first was demonstrated in metals in 2008, and then in nonorganic semiconductors, Vardeny says. In 2013, researchers elsewhere showed it occurred in an organic semiconductor named PEDOT:PSS when it was exposed to continuous microwaves that were relatively weak to avoid frying the semiconductor. [9]

New electron spin secrets revealed: Discovery of a novel link between magnetism and electricity

The findings reveal a novel link between magnetism and electricity, and may have applications in electronics.

The electric current generation demonstrated by the researchers is called charge pumping. Charge pumping provides a source of very high frequency alternating electric currents, and its magnitude and external magnetic field dependency can be used to detect magnetic information.

The findings may, therefore, offer new and exciting ways of transferring and manipulating data in electronic devices based on spintronics, a technology that uses electron spin as the foundation for information storage and manipulation.

The research findings are published as an Advance Online Publication (AOP) on Nature Nanotechnology's website on 10 November 2014.

Spintronics has already been exploited in magnetic mass data storage since the discovery of the giant magnetoresistance (GMR) effect in 1988. For their contribution to physics, the discoverers of GMR were awarded the Nobel Prize in 2007.

The basis of spintronics is the storage of information in the magnetic configuration of ferromagnets and the read-out via spin-dependent transport mechanisms.

"Much of the progress in spintronics has resulted from exploiting the coupling between the electron spin and its orbital motion, but our understanding of these interactions is still immature. We need to know more so that we can fully explore and exploit these forces," says Arne Brataas, professor at NTNU and the corresponding author for the paper.

An electron has a spin, a seemingly internal rotation, in addition to an electric charge. The spin can be up or down, representing clockwise and counterclockwise rotations.

Pure spin currents are charge currents in opposite directions for the two spin components in the material.

It has been known for some time that rotating the magnetization in a magnetic material can generate pure spin currents in adjacent conductors.

However, pure spin currents cannot be conventionally detected by a voltmeter because of the cancellation of the associated charge flow in the same direction.

A secondary spin-charge conversion element is then necessary, such as another ferromagnet or a strong spin-orbit interaction, which causes a spin Hall effect.

Brataas and his collaborators have demonstrated that in a small class of ferromagnetic materials, the spin-charge conversion occurs in the materials themselves.

The spin currents created in the materials are thus directly converted to charge currents via the spin-orbit interaction.

In other words, the ferromagnets function intrinsically as generators of alternating currents driven by the rotating magnetization.

"The phenomenon is a result of a direct link between electricity and magnetism. It allows for the possibility of new nano-scale detection techniques of magnetic information and for the generation of very high-frequency alternating currents," Brataas says. [8]

Simple Experiment

Everybody can repeat my physics teacher's - Nándor Toth - middle school experiment, placing aluminum folios in form V upside down on the electric wire with static electric current, and seeing them open up measuring the electric potential created by the charge distribution, caused by the acceleration of the electrons.

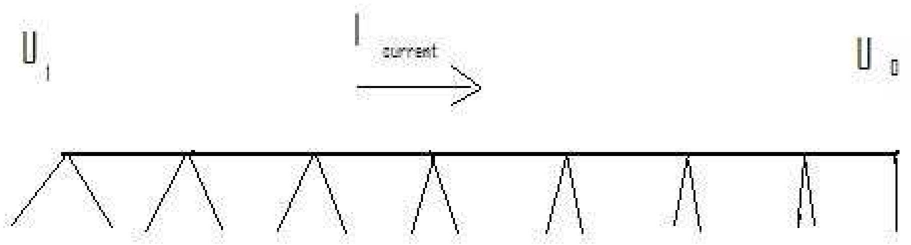

Figure 1.) Aluminium folios shows the charge distribution on the electric wire

He wanted to show us that the potential decreasing linearly along the wire and told us that in the beginning of the wire it is lowering harder, but after that the change is quite linear.

You will see that the folios will draw a parabolic curve showing the charge distribution along the wire, since the way of the accelerated electrons in the wire is proportional with the square of time. The free external charges are moving along the wire, will experience this charge distribution caused electrostatic force and repelled if moving against the direction of the electric current and attracted in the same direction – the magnetic effect of the electric current.

Uniformly accelerated electrons of the steady current

In the steady current **I= dq/dt**, the **q** electric charge crossing the electric wire at any place in the same time is constant. This does not require that the electrons should move with a constant v velocity and does not exclude the possibility that under the constant electric force created by the **E = - dU/dx** potential changes the electrons could accelerating.

If the electrons accelerating under the influence of the electric force, then they would arrive to the **$x = 1/2\ at^2$** in the wire. The **dx/dt = at**, means that every second the accelerating q charge will take a linearly growing length of the wire. For simplicity if a=2 then the electrons would found in the wire at x = 1, 4, 9, 16, 25 …, which means that the dx between them should be 3, 5, 7, 9 …, linearly increasing the volume containing the same q electric charge. It means that the density of the electric charge decreasing linearly and as the consequence of this the U field is decreasing linearly as expected: **-dU/dx = E = const**.

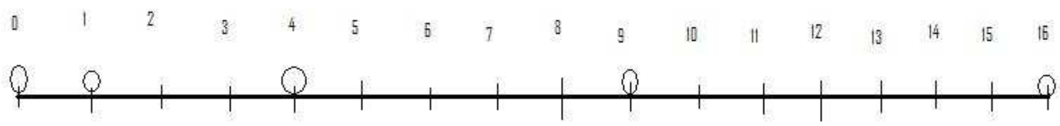

Figure 2.) The accelerating electrons created charge distribution on the electric wire

This picture remembers the Galileo's Slope of the accelerating ball, showed us by the same teacher in the middle school, some lectures before. I want to thank him for his enthusiastic and impressive lectures, giving me the associating idea between the Galileo's Slope and the accelerating charges of the electric current.

We can conclude that the electrons are accelerated by the electric **U** potential, and with this accelerated motion they are maintaining the linear potential decreasing of the **U** potential along they movement. Important to mention, that the linearly decreasing charge density measured in the referential frame of the moving electrons. Along the wire in its referential frame the charge density lowering parabolic, since the charges takes way proportional with the square of time.

The decreasing **U** potential is measurable, simply by measuring it at any place along the wire. One of the simple visualizations is the aluminum foils placed on the wire opening differently depending on the local charge density. The static electricity is changing by parabolic potential giving the equipotential lines for the external moving electrons in the surrounding of the wire.

Magnetic effect of the decreasing U electric potential

One **q** electric charge moving parallel along the wire outside of it with velocity v would experience a changing **U** electric potential along the wire. If it experiencing an emerging potential, it will repel the charge, in case of decreasing **U** potential it will move closer to the wire. This radial electric field will move the external electric charge on the parabolic curve, on the equipotential line of the accelerated charges of the electric current. This is exactly the magnetic effect of the electric current. A constant force, perpendicular to the direction of the movement of the matter will change its direction to a parabolic curve.

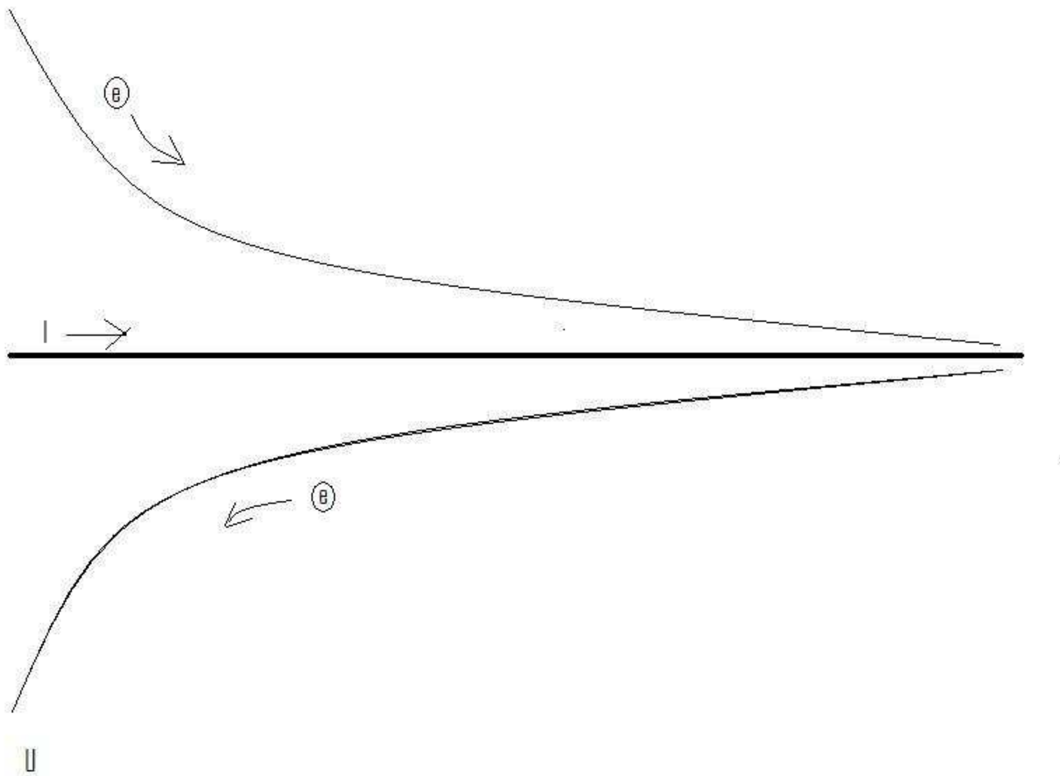

Figure 3.) Concentric parabolic equipotential surfaces around the electric wire causes the magnetic effect on the external moving charges

Considering that the magnetic effect is **F=q v x B**, where the **B** is concentric circle around the electric wire, it is an equipotential circle of the accelerating electrons caused charge distribution. Moving on this circle there is no electric and magnetic effect for the external charges, since **vxB=0**. Moving in the direction of the current the electric charges crosses the biggest potential change, while in any other direction – depending on the angle between the current and velocity of the external charge there is a modest electric potential difference, giving exactly the same force as the **v x B** magnetic force.

Getting the magnetic force from the **F = dp/dt** equation we will understand the magnetic field velocity dependency. Finding the appropriate trajectory of the moving charges we need simply get it from the equipotential lines on the equipotential surfaces, caused by the accelerating charges of the electric current. We can prove that the velocity dependent force causes to move the charges on the equipotential surfaces, since the force due to the potential difference according to the velocity angle – changing only the direction, but not the value of the charge's velocity.

The work done on the charge and the Hamilton Principle

One basic feature of magnetism is that, in the vicinity of a magnetic field, a moving charge will experience a force. Interestingly, the force on the charged particle is always perpendicular to the direction it is moving. Thus magnetic forces cause charged particles to change their direction of motion, but they do not change the speed of the particle. This property is used in high-energy particle accelerators to focus beams of particles which eventually collide with targets to produce new particles. Another way to understand this is to realize that if the force is perpendicular to the motion, then no work is done. Hence magnetic forces do no work on charged particles and cannot increase their kinetic energy. If a charged particle moves through a constant magnetic field, its speed stays the same, but its direction is constantly changing. [2]

In electrostatics, the work done to move a charge from any point on the equipotential surface to any other point on the equipotential surface is zero since they are at the same potential. Furthermore, equipotential surfaces are always perpendicular to the net electric field lines passing through it. [3]

Consequently the work done on the moving charges is zero in both cases, proving that they are equal forces, that is they are the same force.

The accelerating charges self-maintaining potential equivalent with the Hamilton Principle and the Euler-Lagrange equation. [4]

The Magnetic Vector Potential

Also the **A** magnetic vector potential gives the radial parabolic electric potential change of the charge distribution due to the acceleration of electric charges in the electric current.

Necessary to mention that the **A** magnetic vector potential is proportional with a, the acceleration of the charges in the electric current although this is not the only parameter.

The **A** magnetic vector potential is proportional with I**=dQ/dt** electric current, which is proportional with the strength of the charge distribution along the wire. Although it is proportional also with the U potential difference I=U/R, but the R resistivity depends also on the cross-sectional area, that is bigger area gives stronger I and **A**. [7] This means that the bigger potential differences with smaller cross-section can give the same **I** current and **A** vector potential, explaining the gauge transformation.

Since the magnetic field B is defined as the curl of **A**, and the curl of a gradient is identically zero, then any arbitrary function which can be expressed as the gradient of a scalar function may be added to A without changing the value of B obtained from it. That is, A' can be freely substituted for A where

$$\vec{A'} = \vec{A} + \vec{\nabla}\phi$$

Such transformations are called gauge transformations, and there have been a number of "gauges" that have been used to advantage is specific types of calculations in electromagnetic theory. [5]

Since the potential difference and the vector potential both are in the direction of the electric current, this gauge transformation could explain the self maintaining electric potential of the accelerating electrons in the electric current. Also this is the source of the special and general relativity.

The Constant Force of the Magnetic Vector Potential

Moving on the parabolic equipotential line gives the same result as the constant force of gravitation moves on a parabolic line with a constant velocity moving body.

Electromagnetic four-potential

The electromagnetic four-potential defined as:

SI units	cgs units
$A^\alpha = (\phi/c, \mathbf{A})$	$A^\alpha = (\phi, \mathbf{A})$

in which ϕ is the electric potential, and **A** is the magnetic vector potential. [6] This is appropriate with the four-dimensional space-time vector (T, **R**) and in stationary current gives that the potential difference is constant in the time dimension and vector potential (and its curl, the magnetic field) is constant in the space dimensions.

Magnetic induction

Increasing the electric current **I** causes increasing magnetic field **<u>B</u>** by increasing the acceleration of the electrons in the wire. Since l=at, if the acceleration of electrons is growing, than the charge density **dQ/dl** will decrease in time, creating a **–<u>E</u>** electric field. Since the resistance of the wire is constant, only increasing U electric potential could cause an increasing electric current **I=U/R=dQ/dt**. The charge density in the static current changes linear in the time coordinates. Changing its value in time will causing a static electric force, negative to the accelerating force change. This explains the relativistic changing mass of the charge in time also.

Necessary to mention that decreasing electric current will decrease the acceleration of the electrons, causing increased charge density and **<u>E</u>** positive field.

The electric field is a result of the geometric change of the **U** potential and the timely change of the **A** magnetic potential:

E = - dA/dt - dU/dr

$$\mathbf{B} = \nabla \times \mathbf{A}, \quad \mathbf{E} = -\nabla\phi - \frac{\partial \mathbf{A}}{\partial t},$$

The acceleration of the electric charges proportional with the A magnetic vector potential in the electric current and also their time dependence are proportional as well. Since the A vector potential is appears in the equation, the proportional **a** acceleration will satisfy the same equation.

Since increasing acceleration of charges in the increasing electric current the result of increasing potential difference, creating a decreasing potential difference, the electric and magnetic vector potential are changes by the next wave - function equations:

$$\frac{1}{c^2}\frac{\partial^2\varphi}{\partial t^2} - \nabla^2\varphi = \frac{\rho}{\varepsilon_0}$$

$$\nabla^2\mathbf{A} - \frac{1}{c^2}\frac{\partial^2\mathbf{A}}{\partial t^2} = -\mu_0\mathbf{J}$$

The simple experiment with periodical changing **U** potential and **I** electric current will move the aluminium folios with a moving wave along the wire.

The Lorentz gauge says exactly that the accelerating charges are self maintain their accelerator fields and the divergence (source) of the A vector potential is the timely change of the electric potential.

$$\nabla \cdot \vec{A} + \frac{1}{c^2}\frac{\partial\varphi}{\partial t} = 0.$$

Or

$$\vec{E} = -\nabla\varphi - \frac{\partial\vec{A}}{\partial t}.$$

The timely change of the A vector potential, which is the proportionally changing acceleration of the charges will produce the negative electric field.

Lorentz transformation of the Special Relativity

In the referential frame of the accelerating electrons the charge density lowering linearly because of the linearly growing way they takes every next time period. From the referential frame of the wire there is a parabolic charge density lowering.

The difference between these two referential frames, namely the referential frame of the wire and the referential frame of the moving electrons gives the relativistic effect. Important to say that the moving electrons presenting the time coordinate, since the electrons are taking linearly increasing way every next time period, and the wire presenting the geometric coordinate.

The Lorentz transformations are based on moving light sources of the Michelson - Morley experiment giving a practical method to transform time and geometric coordinates without explaining the source of this mystery.

The real mystery is that the accelerating charges are maintaining the accelerating force with their charge distribution locally. The resolution of this mystery that the charges are simply the results of the diffraction patterns, that is the charges and the electric field are two sides of the same thing. Otherwise the charges could exceed the velocity of the electromagnetic field.

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.

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 the 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.

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 = dx dp** or **1/2 h = dt dE**, that is the value of the basic energy status, consequently related to the m_o inertial mass of the fermions.

The photon's 1 spin value and the electric charges 1/2 spin gives us the idea, that the electric charge and the electromagnetic wave two sides of the same thing, 1/2 – (-1/2) = 1.

Fine structure constant

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

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

Since the frequency ***ν*,** wavelength ***λ***, and speed of light ***c*** are related by ***λν* = *c***, the Planck relation can also be expressed as

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

Since this is the source of the 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, since **$E = mc^2$**.

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.

Planck Distribution Law

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! 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 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.

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. [1]

Electromagnetic inertia and Gravitational attraction

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

It looks clear that the growing acceleration results the relativistic growing mass - limited also with the velocity of the electromagnetic wave.

The negatively changing acceleration causes a positive electric field, working as a decreasing mass.

Since ***E = hν*** and ***E = mc²***, ***m = hν /c²*** that is the ***m*** depends only on the ***ν*** frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the m_o inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

If the mass is electromagnetic, then the gravitation is also electromagnetic effect caused by the magnetic effect between the same charges, they would attract each other if they are moving parallel by the magnetic effect.

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 the measured effect of the force of the gravitation, since the magnetic effect depends on this closeness. This way the mass and the magnetic attraction depend equally on the wavelength of the electromagnetic waves.

Conclusions

The generation and modulation of high-frequency currents are central wireless communication devices such as mobile phones, WLAN modules for personal computers, Bluetooth devices and future vehicle radars. [8]
Needless to say that the accelerating electrons of the steady stationary current are a simple demystification of the magnetic field, by creating a decreasing charge distribution along the wire, maintaining the decreasing U potential and creating the **A** vector potential experienced by the electrons moving by **v** velocity relative to the wire. This way it is easier to understand also the time dependent changes of the electric current and the electromagnetic waves as the resulting fields moving by c velocity.
There is a very important law of the nature behind the self maintaining **E** accelerating force by the accelerated electrons. The accelerated electrons created electromagnetic fields are so natural that they occur as electromagnetic waves traveling with velocity c. It shows that the electric charges are the result of the electromagnetic waves diffraction.
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 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. Basing the gravitational force on the 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.

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