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Advancement in Communication and Security with Quantum Physics and Mechanics

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Abstract- This paper presents the inventions and discoveries already made in quantum physics which are used now as the main base. It also contains the new technology that has come up by various scientists studying it and researching over it. The invention of quarks and neutrinos has not been an easy task. This paper proposes a new outlook with which we can start thinking in developing communication and technology.

Index Terms- Carbon nanotube, Schrödinger's Equation, De Broglie Equation, Uncertainty Principle

I. Introduction

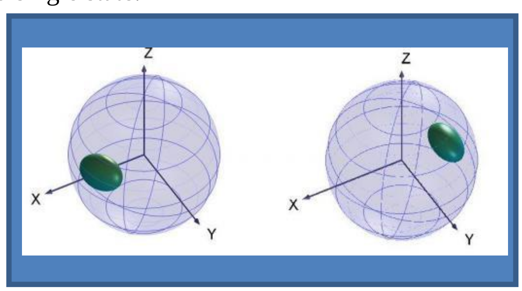
The world that had started with a small particle has grown to a giant mass. And all this was discovered by the people who think as to why. To start with, the thought that the world was made up of small particles was practically proved by Neil Bohr. His Copenhagen Interpretation that a particle sometimes acts as a particle and sometimes as a wave surprised everyone. Erwin Schrödinger created quantum equations based on wave mathematics, a mathematical system that corresponds to the world we know much more than the matrices. After the initial shock, first Schrödinger himself then others proved that the equations were mathematically equivalent. Bohr then invited Schrödinger to Copenhagen where they found that Schrödinger's waves were in fact not like real waves. Also, each particle that was described as a wave required three dimensions.

Schrödinger also said that particles still jumped from one quantum state to another; even expressed in terms of waves space was still not continuous. All this incomplete conclusions are still continuing today. Even today people try to imagine the atomic world as being a bunch of classical waves. The equations that Schrödinger gave were used even later for other observations. Even Bohr used those equations in his Copenhagen Interpretation. Werner Heisenberg proposed in 1925 that it is in fact *physically impossible* to do so. As he stated it in what now is called the Heisenberg Uncertainty Principle, if you determine an object's position with uncertainty x, there must be an uncertainty in momentum, p, such that $xp > h/4pi$, where h is Planck's constant. Contradicting the Uncertainty Principle, in 1935, Einstein and two other physicists, Podolski and Rosen, presented what is now known as the EPR paper in which they suggested a way to do just that. The idea is this: set up an interaction such that two particles are go off in opposite directions and do not interact with anything else. Wait until they are far apart, and then measure the momentum of one and the position of the other. Because of conservation of momentum, you can determine the momentum of the particle not measured, so when you measure its position you know both its momentum and position. The only way quantum physics could be true is if the particles could communicate faster than the speed of light, which Einstein reasoned would be impossible because of his Theory of Relativity.

II. Brief Description of Latest Technology

A. ATOM'S SPIN

Researchers suggest one can affect an atom's spin by adjusting the way it is measured. All spin directions (represented by the spheres) collapse on one or the opposite direction depending on the measured photon polarization. One of the most basic laws of quantum mechanics is that a system can be in more than one state. It can exist in multiple realities – at once. This phenomenon, known as the superposition principle, exists only so long as the system is not observed or measured in any way. As soon as such a system is measured, its superposition collapses into a single state.



B. QUANTUM INFORMATION PROCESSING

Researchers from Yale, Surrey, and Paris have made an important breakthrough towards 'quantum information processing, which promises to lead to massive information technology advancement in the future. Quantum information allows for the ultimate information processing unit in terms of accuracy, distance of coverage, knowledge when eavesdropped, simplicity in design of parallel systems and potential bandwidth. In the current issue of Nature, researchers have demonstrated a new approach for the manipulation of quantum states of light. Photons need to interact with each other sufficiently strongly for this to be achieved. This was made possible by engineering a device where photons interact with each other even when only a few photons are present but at the same time the fragile quantum state is not destroyed by the environmental noise. Dr. Eran Ginossar, one of the authors who conceived the idea, based at the Advanced Technology Institute (ATI) at the University of Surrey said: "What makes this discovery so exciting is that up to date it has been considered very difficult to engineer strong interactions between localised photons. This will open up a way of encoding quantum information directly to photons in one of the most promising architectures of quantum computing". Professor Ravi Silva, Director of the ATI, commented: "Previously envisaged bottlenecks to quantum information processing (QIP) over large areas and distances will now be enabled by this breakthrough. QIP is predicted to lead to enhance computing and communication even beyond the solutions to the spectrum crunch being resolved by the recently established 5G Innovation Centre at Surrey.

C. QUANTUM COMPUTERS COUNTING ON CARBON NANOTUBES

Using quantum mechanical phenomena, computers could be much more powerful than their classical digital predecessors. Scientists all over the world are working to explore the basis for quantum computing. To date most systems are based on electrically charged particles that are held in an "electromagnetic trap." A disadvantage of these systems is that they are very sensitive to electromagnetic interference and therefore need extensive shielding. Physicists at the Technische Universitaet Muenchen have now found a way for information to be stored and quantum mechanically processed in mechanical vibrations.

Carbon nanotubes can be used as quantum bits for quantum computers. A study by physicists at the Technische Universitaet Muenchen (TUM) has shown how nanotubes can store information in the form of vibrations. Up to now, researchers have experimented primarily with electrically charged particles. Because Nano mechanical devices are not charged, they are much less sensitive to electrical interference.

A carbon nanotube that is clamped at both ends can be excited to oscillate. Like a guitar string, it vibrates for an amazingly long time. "One would expect that such a system would be strongly damped, and that the vibration would subside quickly," says Simon Rips, first author of the publication. "In fact, the string vibrates more than a million times. The information is thus retained up to one second. That is long enough to work with."

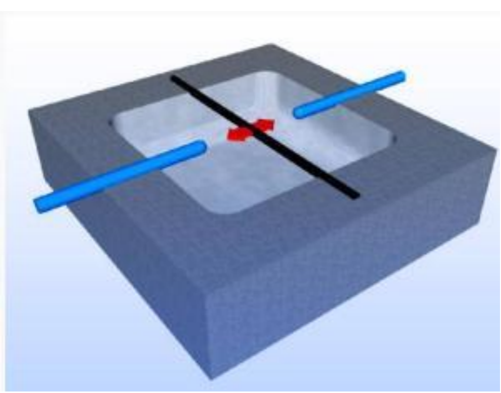


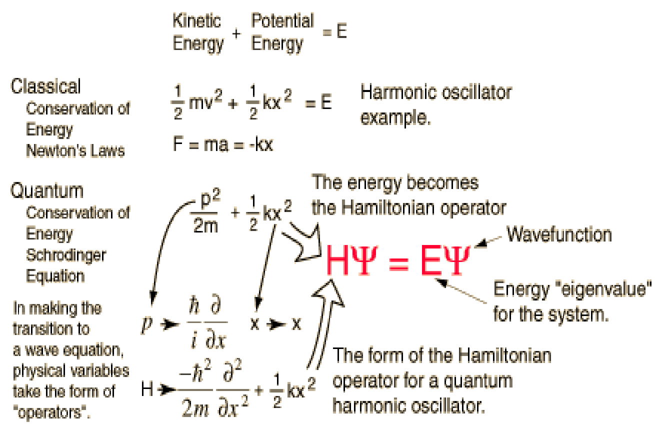
FIG: ***Like a guitar string nanotubes (black) can be clamped and excited to vibrate. An electric field (electrodes: blue) ensures that two of the many possible states can be selectively addressed. (Credit: M.J. Hartmann, TUM)***

Since such a string oscillates among many physically equivalent states, the physicists resorted to a trick: an electric field in the vicinity of the nanotube ensures that two of these states can be selectively addressed. The information can then be written and read opto electronically. "Our concept is based on available technology," says Michael Hartmann, head of the Emmy Noether research group Quantum Optics and Quantum Dynamics at the TU Muenchen. "It could take us a step closer to the realization of a quantum computer."

III. QUANTUM RELATED EQUATION

A. Schrödinger's Equation

The Schrodinger equation plays the role of Newton's laws and conservation of energy in classical mechanics - i.e., it predicts the future behaviour of a dynamic system. It is a wave equation in terms of the wave function which predicts analytically and precisely the probability of events or outcome. The detailed outcome is not strictly determined, but given a large number of events, the Schrodinger equation will predict the distribution of results.



The kinetic and potential energies are transformed into the Hamiltonian which acts upon the wave function to generate the evolution of the wave function in time and space. The Schrodinger equation gives the quantized energies of the system and gives the form of the wave function so that other properties may be calculated.

B. Particle in the box

The idealized situation of a particle in a box with infinitely high walls is an application of the Schrodinger equation which yields some insights into particle confinement. The wave function must be zero at the walls and the solution for the wave function yields just sine waves.

The longest wavelength is

$$\lambda = 2L$$

and the higher modes have wavelengths given by

$$\lambda = \frac{2L}{n} \text{ where } n = 1,2,3,4 \ldots$$

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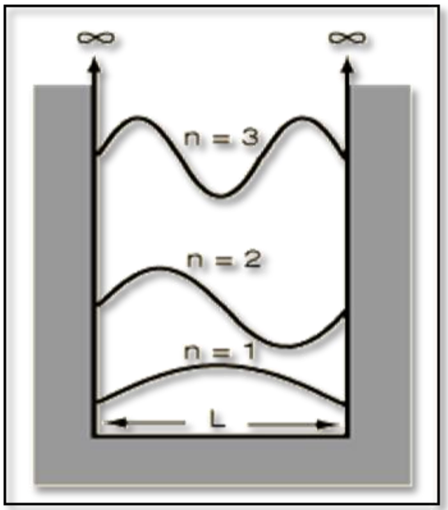
When this is substituted into the De Broglie relationship it yields momentum

$$p = \frac{h}{\lambda} = \frac{nh}{2L}$$



When the momentum expression for the particle in a box :

$$p = \frac{h}{\lambda} = \frac{nh}{2L} \quad \text{where } n = 1, 2, 3, 4 \ldots$$

It is used to calculate the energy associated with the particles

$$\frac{1}{2}mv^2 = \frac{p^2}{2m} = \frac{n^2h^2}{8mL^2} = E_n$$

Energy for nth quantum state for particle in infinite box.

Though oversimplified, this indicates some important things about bound states for particles:

1. The energies are quantized and can be characterized by a quantum number n
2. The energy cannot be exactly zero.
3. The smaller the confinement, the larger the energy required.

If a particle is confined into a rectangular volume, the same kind of process can be applied to a three-dimensional "particle in a box", and the same kind of energy contribution is made from each dimension. The energies for a three-dimensional box are

$$E = \frac{\left(n_1^2 + n_2^2 + n_3^2\right)h^2}{8mL^2}$$

This gives a more physically realistic expression for the available energies for contained particles. This expression is used in determining the density of possible energy states for electrons in solids.

C. Carbon Atom

The carbon atom, in particular an atom of the isotope ^{14}C, has been chosen to illustrate the implications of quantum mechanics for the energy required to confine a particle to a region of space. Without recourse to the details of the nature of the fundamental forces, quantum mechanics gives the insight that it takes 10's of electron volts to contain electrons in atoms, and energies on the order of MeV's to contain protons in nuclei.

Taking the diameter of a carbon atom from the periodic table and calculating the minimum energy consistent with the uncertainty principle for a cubical volume of that dimension, we obtain a value of 10.4 eV. This compares with the observed value of 11.3 eV for the first ionization potential for the carbon atom. If we calculate the minimum confinement energy for the proton in a space the size of a carbon atom, we find that to be only 0.0056 eV. This extremely low energy can be compared with the average thermal energy of 0.04 eV at 300K! This implies that the proton, with only the energy provided by the internal energy of the normal environment can just wander in and out of an atomic space.

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When we apply the minimum energy calculation to the carbon nucleus, the picture is very different. The confinement energy for keeping a proton inside the cubical volume of dimension equal to the nuclear diameter is 5.6 MeV.

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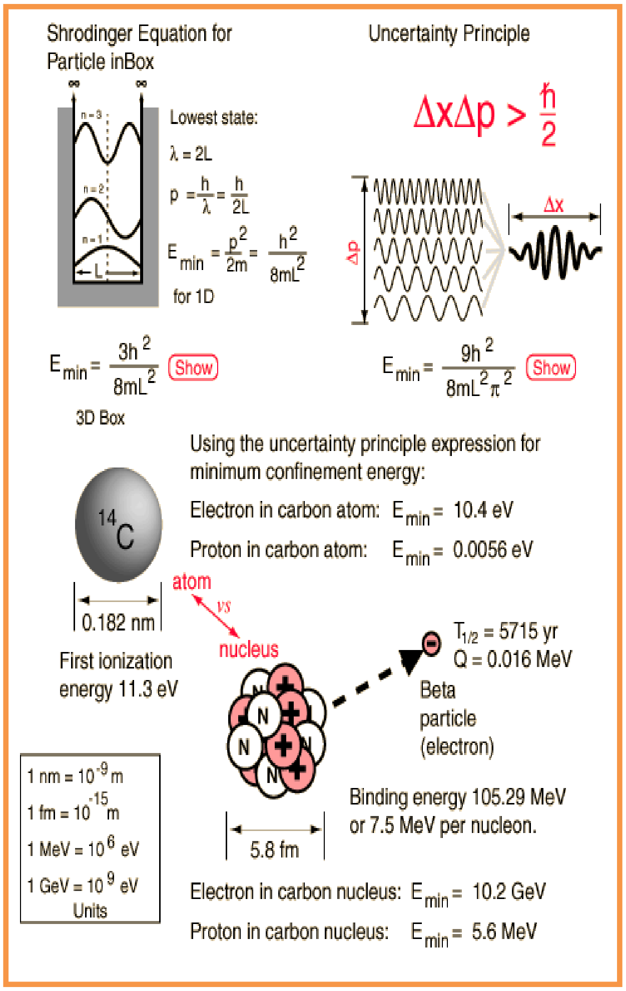

This compares well in magnitude with the observed average binding energy of 7.5 MeV for nucleons in the carbon-14 nucleus. So with no tools other than the uncertainty principle, we have established the scale of energy for nuclear processes. Observed radioactive processes are in the range 0-10 MeV, and this is consistent with the uncertainty principle.

The story for the electron is more dramatic. We observe electrons being emitted from the carbon-14 nucleus (beta decay) with the relatively small energy of 0.016 MeV. Does that imply that there are electrons hanging around inside the carbon nucleus? Definitely not!! The minimum confinement energy for an electron in the nuclear volume is a preposterously high 10.2 GeV, a half-million times greater than the observed decay energy of the carbon-14 nucleus. The calculation of required confinement energy then implies that the observed electron has been created inside the nucleus as a part of the radioactive decay process rather than being simply an ejection of an electron which was already there.

IV. New Prospects

We can use the concept of quantum mechanics to find the distance between very small particles. We can analyse very tiny world. Scientist Werner Heisenberg found that subatomic particles can be present in more than one place at a time. In travelling from one place to another they don't even need to travel that distance. It is astonishing to know they can emerge out from any object and can also vanish when they want. Hence they are called as virtual particles.

By use this concept we can control a particular system which is far away from us. For example: when we travel in train we can know its working. How the operator gets the information that train must be stopped in a particular area. It is from the signal that he gets .Hence we can operate system by sending the information which can reach faster than the speed of light, as these are virtual particles. Through this we can make the communication faster and give the desire response. We know by now that there is a link between particles near and far. There is a link that synchronizes them. They acquire the same properties. If one particle is moving clockwise and has some speed then the other will also rotate with the same speed. But to maintain the law of nature, it will move anticlockwise. This concept can be used in running and controlling heavy machinery which are far and need vigilance from one specific point. We can make that link by making use of electromagnetic waves. We can send our data with very high speed to one place to another place. It can also be used for security purposes and the span of time with which we get the information will be very minute. In a fraction of seconds we will be able to detect the error at a place and the victim can be aided.

V. Conclusion

Quantum physics is such a vast topic, yet to be understood properly. But, scientists have contributed their whole strength and life in improving the technology to make the world comfortable. Everything that we observe has science hidden in that. Quantum has turned the thinking from macro to nanotechnology. The study of physics is interesting and mind boggling if one understands it and can relate it with the reality. So much improvement can be made still and hence we have to keep proposing ideas and accept those ideas from different individuals

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