

Wave-Particle Paradox and Evans Photomagnetron

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1.0 INTRODUCTION

Physical objects from quarks to planets have wavelike attributes. Quantum theory offers a mathematical model for the observed wave-particle dualism. This article gives a physical model for the wave-particle duality nature of photons, electrons, protons, neutrons, atoms and molecules. It explains the non-thermal, simple harmonic motion, intrinsic electromagnetic inertia, resonance Compton frequency, oscillation nature of atomic and subatomic particles.

The article conjectures that a photon is a magnetic dipole. It gives a physical interpretation of wave mechanics, two-slit interference, the Faraday effect, the inverse Faraday effect (IFE) and the photon string theory. It predicts the existence of Planck photons, dark photons and zero point photons. Also given is an explanation for the magnetic field of a black hole, neutron star and the Sun.

2.0 SUBATOMIC & ATOMIC PARTICLES

An atomic or a subatomic particle is never at rest.

For example, an atom or a molecule in a solid is oscillating, very nearly, in a simple harmonic motion (SHM) about a rest or fixed mean or equilibrium position even at zero kelvin temperature.

2.1 The ELECTRON

An electron is a subatomic elementary particle with the smallest non-zero rest mass. It has a negative electric charge, which generates a field in free

space, extending to infinity, and is conversely acted on by forces due to the field.

Assume an isolated electron in free space to be at rest, at the origin in a given inertial frame of reference. Let this electron be subject to a tiny force F in the (+) Y-axis direction.

A uniformly accelerating electron gives rise to a uniformly changing electric field. This will induce a uniformly changing magnetic field, which will induce a uniformly changing electric field, so as to oppose the initial change in the electric field. This will cause the electron to decelerate and come to rest at some point (+a) on the Y-axis.

The decelerating electromagnetic force on the electron will continue to act in the plus (+) Y-axis direction and cause the electron to accelerate in the minus (-) Y-axis direction. Since, deceleration in the plus (+) Y-axis direction is equal to acceleration in the minus (-) Y-axis direction. The electron will accelerate towards the origin.

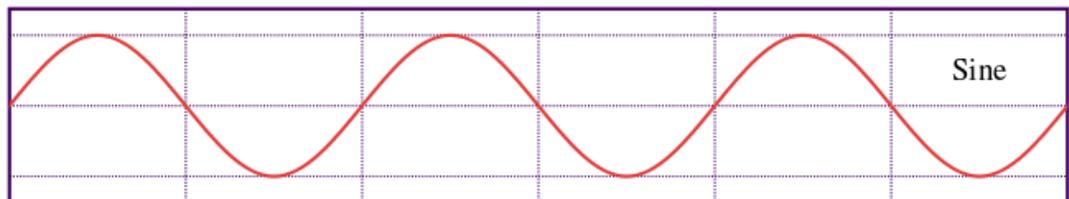
The initial force F will now be acting in the minus (-) Y-axis direction. This force will carry the electron to a point 'minus a' (-a) on the Y-axis, where the electron will come to rest, change direction and accelerate towards the origin. And so on.

http://upload.wikimedia.org/wikipedia/commons/7/74/Simple_harmonic_motion_animation.gif

- *A static electron in free space does not have a uniform motion in a straight line in a given inertial frame of reference, but is not a fixed particle at rest. It is oscillating in a SHM in its own rest frame.*

- *An oscillating electric field creates an oscillating magnetic field.*
- *An oscillating magnetic field creates an oscillating electric field.*
- *An electric field is a vector field. A magnetic field is also a vector field.*
- *But, an electromagnetic field is a tensor field.*
- *Instead of using two vector fields describing the electric and magnetic fields separately, a tensor field representing these two fields together is used.*

An electron which is oscillating along the Y-axis, in a SHM, with its rest or fixed mean or equilibrium position at the origin; when subject to a force in the (+) X-axis direction at the origin, will move along a sine wave path in the XY-plane, in the (+) X-axis direction, even at relativistic velocities.



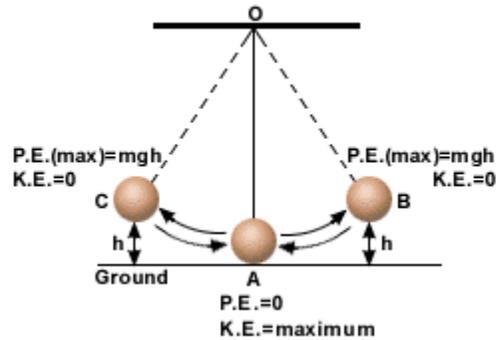
- *An electron moves, not in a straight line but, along a sine wave path. This explains the physical concept of the wave-particle nature of the electron.*

However, a hypothetical electron with zero electric charge, at rest at the origin in a given inertial frame of reference, when subject to a force in the (+) X-axis direction, will move with a uniform motion in a straight line in the (+) X-axis direction.

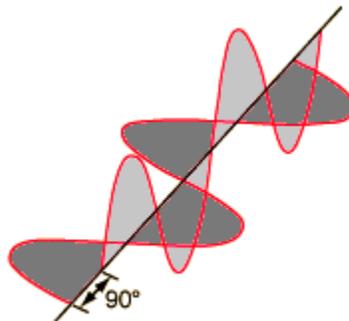
- A hypothetical electron without a charge is like the bob of a simple pendulum without a string.

The intrinsic electromagnetic oscillation nature of an isolated electron in free space, is in accordance with the law of conservation of energy and is similar to an ideal simple pendulum oscillating in a SHM in the earth's gravitational field.

The potential (gravitational) field vector direction (Y-axis) and the kinetic (velocity) field vector direction (X-axis) of a SHM oscillating ideal simple pendulum are orthogonal. The potential field and the kinetic field are in phase quadrature. This implies that when the potential energy is maximum, the kinetic energy or velocity is zero. And, when the potential energy is minimum, the kinetic energy or velocity is maximum. The potential energy plus kinetic energy is always a constant.



Similarly,



The transverse electric (E) and magnetic (H) fields of a SHM oscillating electron (at rest or uniformly moving) are orthogonal and in phase quadrature. The electric field energy plus magnetic field energy is always a constant.

This SHM, standing wave, intrinsic electromagnetic inertia generating resonance is at the electron Compton frequency, as per de Broglie. The electron rest mass is equivalent to the energy of a photon of wavelength equal to the electron Compton wavelength. An analysis of the oscillating electron is also given by Petr Beckmann [1].

The earth's conservative gravitational field is external to the simple pendulum. However, an electron oscillates in a SHM, in its own electromagnetic inertia field, even at zero kelvin temperature. Oscillations can be thermal or electromagnetic. Thermal oscillations tend to zero as the temperature tends to zero kelvin. At zero kelvin we are left with only the electromagnetic oscillations.

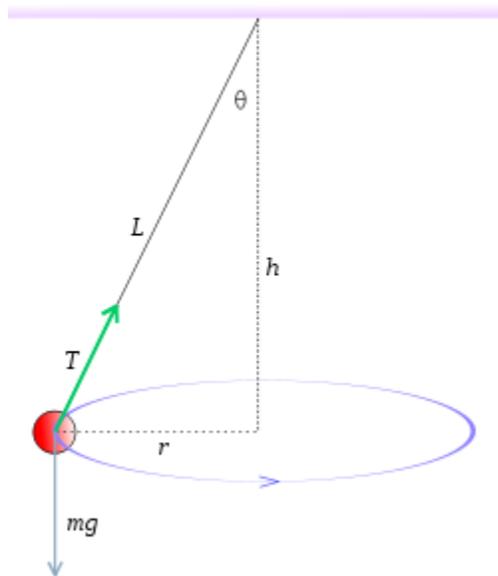
This is non-thermal, zero point vibration at absolute zero. The zero point energy is the lowest possible vibration energy. By wave mechanics, the zero-point energy for a linear simple harmonic oscillator of frequency (f) is $\frac{1}{2} hf$, where (h) is the Planck constant.

As per Galileo's law of inertia or Newton's first law of motion, a physical body is either at rest in a given inertial frame of reference or will continue to move with a uniform motion in a straight line with a constant velocity. Similarly, an ideal simple pendulum is either at rest or will continue to oscillate for ever in a SHM, unless acted upon by an external force to change it.

An isolated electron in free space is always oscillating in a SHM in its own rest frame. This non-thermal, SHM, standing wave, intrinsic electromagnetic inertia, resonance Compton frequency, oscillation is as fundamental as:

- The uniform motion in a straight line, law of linear inertia or the conservation of linear momentum and,
- The law of rotational inertia or the conservation of angular momentum.

An ideal simple pendulum will oscillate in a SHM along a linear path or, along an elliptical or a circular path (**conical pendulum**). Similarly, an electron oscillates in a SHM along a linear path or, along an elliptical or a circular (clockwise or anti-clockwise) path, corresponding to the electron's intrinsic magnetic moment (spin up or spin down). An electron with spin behaves like a tiny magnet. This also gives a physical picture of the Schrödinger zitterbewegung (zbw) theory. See #11.0



A **conical pendulum** is a simple pendulum in which the bob moves at a constant speed in a horizontal circle with the string tracing out a cone.

The time period, for a very small radius of swing only, is the same as for the simple pendulum.

In the Wave mechanics of Dirac, the intrinsic magnetic moment associated with the spin of an electron would be exactly one Bohr magneton, a fundamental constant. Quantum Electro Dynamics, QED shows that a small difference can be expected.

2.2 The PROTON

A proton is a subatomic particle with a positive electric charge equal in magnitude to the negative electric charge of an electron.

In a manner similar to the electron, an isolated proton in free space exhibits non-thermal, SHM, standing wave, intrinsic electromagnetic inertia, oscillations (linear, elliptical or circular) in its own rest frame.

The transverse electric (E) and magnetic (H) fields of a SHM oscillating proton are orthogonal and in phase quadrature. The electric field energy plus magnetic field energy is always a constant. This SHM, electromagnetic inertia generating resonance is at the proton Compton frequency.

The mass of a proton is 1836 times that of an electron. So, the amplitude of a proton oscillation is 1836 times less than that of an electron. The Compton wavelength is characteristic of the mass of a particle, and for a proton is 1/1836 times that of an electron. The proton rest mass is equivalent to the energy of a photon of wavelength equal to the proton Compton wavelength.

2.3 The NEUTRON

A neutron is an electrically neutral, subatomic particle, having a mass 1839 times that of an

electron. Neutrons are, individually, tiny magnets. The magnetic moment of a neutron suggests that it has an internal structure of electric charge, although the net charge is zero. A neutron is like a magnetic dipole with a N-pole and a S-pole.

Assume an isolated neutron in free space to be at rest at the origin in a given inertial frame of reference, with its magnetic NS-axis along the y-axis. Let this neutron be subject to a tiny force F in the (+) Y-axis direction.

A uniformly accelerating neutron gives rise to a uniformly changing magnetic field. This will induce a uniformly changing electric field, which will induce a uniformly changing magnetic field, so as to oppose the initial change in the magnetic field. This will cause the neutron to decelerate and come to rest at some point (+b) on the Y-axis.

The decelerating electromagnetic force on the neutron will continue to act in the plus (+) Y-axis direction and cause the neutron to accelerate in the minus (-) Y-axis direction. Since, deceleration in the plus (+) Y-axis direction is equal to acceleration in the minus (-) Y-axis direction. The neutron will accelerate towards the origin.

The initial force F will now be acting in the minus (-) Y-axis direction. This force will carry the neutron to a point 'minus b' (-b) on the Y-axis, where the neutron will come to rest, change direction and accelerate towards the origin. And so on.

In a manner similar to the electron or a proton, an isolated neutron in free space exhibits non-thermal, SHM, standing wave, intrinsic electromagnetic inertia, oscillations (linear, elliptical or circular) in its own rest frame.

The transverse magnetic (H) and electric (E) fields of a SHM oscillating neutron are orthogonal and in phase quadrature. The magnetic field energy plus electric field energy is always a constant. This SHM, electromagnetic inertia generating resonance is at the neutron Compton frequency. The neutron rest mass is equivalent to the energy of a photon of wavelength equal to the neutron Compton wavelength.

2.4 ATOMS & MOLECULES

Atoms and molecules have a zero net electric charge. Polar molecules have an electric moment.

Atoms or molecules with unpaired electrons are paramagnetic and possess a magnetic moment. It is caused by the intrinsic spins of electrons.

<http://en.wikibooks.org/wiki/File:Paramag.png>

There is also a contribution to the magnetic properties from the orbital motion of the electron. Diamagnetism is caused by the motion of electrons in atoms around the nuclei. An orbiting electron produces a magnetic field.

Atoms or molecules possess a net electronic magnetic moment. This is the total magnetic dipole moment associated with the orbital motion of all the electrons of an atom and the intrinsic electron spins. The total electronic magnetic moment of an atom depends on the state of coupling between the orbital and intrinsic spin angular momentum of the electrons.

The atomic nucleus has an electric and a magnetic moment of its own. The nuclear magnetic moment of an atomic nucleus arises from the intrinsic spin of the protons and neutrons. It is mainly a magnetic dipole moment. The nuclear magnetic moment

varies from isotope to isotope of an element. It can only be zero if the numbers of protons and of neutrons are both even.

The nuclear magnetic dipole moment is given in units of 'nuclear magneton' which is 1836 times weaker than atomic magnetic moments, orbital or intrinsic, (Bohr magneton). The magnetic moment of a proton is 2.79 nuclear magnetons.

An atom or a molecule is a magnetic dipole. In a manner similar to the neutron, an isolated atom or a molecule in free space exhibits non-thermal, SHM, standing wave, intrinsic electromagnetic inertia, oscillations (linear, elliptical or circular) in its own rest frame.

The transverse magnetic (H) and electric (E) fields of a SHM oscillating atom or a molecule are orthogonal and in phase quadrature. The magnetic field energy plus electric field energy is always a constant.

This SHM, electromagnetic inertia generating resonance is at the atom or the molecule Compton frequency. The rest mass of an atom or a molecule is equivalent to the energy of a photon of wavelength equal to the atom or the molecule Compton wavelength.

The SHM vibrations of atoms or molecules in a solid at zero kelvin temperature is due to their own electromagnetic inertia field, which is the cause of the non-thermal, zero point vibration energy at absolute zero.

2.5 The PHOTON

- *“For the rest of my life, I will reflect on what light is.”*

Albert Einstein, 1917.

- *All these fifty years of conscious brooding have brought me no closer to the answer to the question: 'What are light quanta?'*
Albert Einstein, 1954.
- *"I therefore take the liberty of proposing for this hypothetical new atom, which is not light but plays an essential part in every process of radiation, the name PHOTON."*
Gilbert Newton Lewis, 1926.

Light quantum or a photon is a quantum of electromagnetic radiation and an elementary particle with a zero electric charge. A photon is an electromagnetic object. It is never at rest. A photon has energy and momentum.

A photon has a real longitudinal magnetic field $B(3)$ whose quantum equivalent is the Evans photomagnetron, which has all the known properties of magnetic flux density (Tesla = Weber per square meter). Circular or elliptical polarized light acts as a magnet upon interaction with matter. This is the 'inverse Faraday effect' (IFE). Un-polarized light does not exhibit IFE.

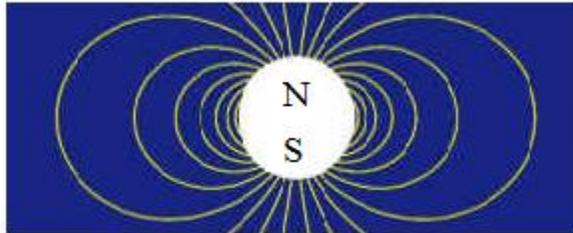
This magnetization is proportional to the light intensity [6], and the light intensity is proportional to the photon flux density, as per Einstein's correlation of the number of photons in a light beam with its intensity. A circular polarized laser beam of intensity 10^4 W m^{-2} (1 W cm^{-2}), the magnitude of the longitudinal magnetic field is about 10^{-5} Tesla or about 0.1 G, roughly a tenth of the earth's magnetic field [6].

The real longitudinal magnetic field $B(3)$ of the photon was discovered in 1992 by Professor Myron

Wyn Evans [4,5,6]. This was a landmark historical event, with far reaching insights, in our understanding of the physical nature of the enigmatic photon.

The $B(3)$ field gave rise to the theory of $O(3)$ electrodynamics, which has been the key in helping Evans complete Einstein's work on the unified field theory. $O(3)$ electrodynamics is a theory of General Relativity and is a consequence of the fact that 3D space has an $O(3)$ symmetry. $O(3)$ symmetry implies invariance under rotations and reflections [22].

The longitudinal electric field $E(3)$ of a photon is imaginary (complex numbers). The transverse orthogonal magnetic (H) and electric (E) fields of a photon are real. The photon is its own antiphoton since it has no charge, baryon number, lepton number or strangeness. The direction of the real longitudinal magnetic field is opposite for photon and antiphoton [6].



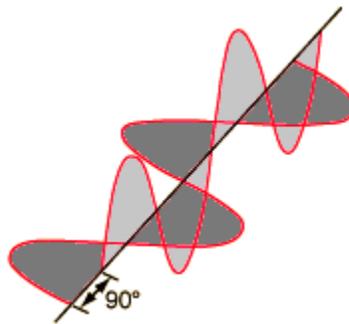
- **CONJECTURE:** The photon, a quantum of electro-magnetic radiation, is a magnetic dipole.

This physical model of the photon helps us in understanding the wave-particle nature of the photon, the two-slit interference, the Faraday effect and the inverse Faraday effect (IFC). An anti-photon is a photon with its magnetic polarity reversed, that is, from NS to SN or vice versa.

In a manner similar to the neutron, the transverse magnetic (H) and electric (E) fields of a photon are orthogonal and in phase quadrature. The magnetic field energy plus electric field energy is always a constant. This contributes to the electromagnetic inertia, SHM oscillations (linear, elliptical or circular) of the photon.

In free space, photons always travel with the fundamental speed of light ($c=3 \times 10^8$ m/s, a universal constant of relativity), at all times, in all directions, in all inertial frames, independent of the relative motion of sources and detectors.

- *Photons or electromagnetic waves are self propagating.*
- *CONJECTURE: This is possible only if the transverse magnetic and electric fields are in phase quadrature.*



- *The mathematical model of the Maxwell's equations needs to be modified, so as to reflect on the phase quadrature relationship between the photon's transverse magnetic (H) and the electric (E) fields.*
- *The mathematical symmetry of the free space Maxwell's equations, imply that the magnitudes of the transverse orthogonal*

magnetic (H) and electric (E) fields are physically equivalent. However, their numerical values in SI units are not equal since, the permeability and permittivity of free space have unequal numerical values in SI units.

- *In the case of an ideal simple pendulum the magnitudes of the transverse orthogonal kinetic (velocity) and potential (gravitational) fields are also physically equivalent and their numerical values in SI units are equal.*

3.0 RESONANCE COMPTON FREQUENCY

The electric charge of a subatomic particle may be negative, positive or zero. However, all atomic and subatomic particles have an intrinsic magnetic moment.

- An *electron* has a negative electric charge and an intrinsic magnetic moment, spin up or spin down.
- A *proton* has a positive electric charge and an intrinsic magnetic moment.
- A *neutron* has a zero net electric charge but has an intrinsic magnetic moment.
- *Atoms and molecules* have a zero net electric charge but exhibit an intrinsic magnetic moment.
- A *photon* is a magnetic dipole with a N-pole and a S-pole.

As explained in #2.1–2.4, the intrinsic electromagnetic nature of atoms, molecules or a subatomic particle explains why an atom, molecule or a subatomic particle is never at rest even at zero kelvin but, exhibits non-thermal, SHM, standing wave, intrinsic electromagnetic inertia, resonance Compton frequency oscillations (linear, elliptical or circular) in its own rest frame.

This also explains the zero point energy (ZPE) or ZP oscillations of an atomic or a subatomic particle. ZPE is non-thermal, electromagnetic lowest possible energy, which is at zero kelvin and is non-zero. The ZP oscillations (linear, elliptical or circular) are a natural property of an atomic or a subatomic particle. ZPE is the lowest possible energy that a quantum mechanical physical system may possess. It is the energy of the ground state of the system.

Absolute zero temperature is a state at which no further energy can be extracted from a physical body. Only thermal energy can be removed from a particle, whereas ZPE is non-thermal and electromagnetic in nature.

For an electron with rest mass energy \mathbf{E} , rest mass \mathbf{m} , and frequency \mathbf{f} , we have:

$$\mathbf{E} = \mathbf{mc}^2 \quad \text{and} \quad \mathbf{E} = \mathbf{hf}$$

Where, \mathbf{c} is the speed of light and \mathbf{h} is the Planck constant.

$$\text{So, } \mathbf{mc}^2 = \mathbf{hf} \quad \text{and} \quad \mathbf{f} = (\mathbf{mc}^2)/\mathbf{h}$$

According to de Broglie, $(\mathbf{mc}^2)/\mathbf{h}$ is the electron **Compton frequency** and is a fundamental intrinsic oscillation of the electron. An electron is always oscillating at the Compton frequency in its own rest frame. This inertia generating resonance is only at the electron Compton frequency. De Broglie described this equivalence $(\mathbf{mc}^2 = \mathbf{hf})$ between mass and the energy of oscillation motion as 'a great law of nature'. An atomic or a subatomic particle vibrates naturally at its resonance Compton frequency.

Also, (\mathbf{h}/\mathbf{mc}) is the electron **Compton wavelength**. An electron cannot be confined to a region smaller than its

Compton wavelength. For an electron oscillating in a linear SHM, the Compton wavelength is twice the amplitude. For an electron oscillating in a circular SHM (conical pendulum), the Compton wavelength is equal to the diameter.

The electron rest mass is equivalent to the energy of a photon of wavelength equal to the electron Compton wavelength. Similarly, the rest mass of an atom, molecule or a subatomic particle is equivalent to the energy of a photon with a wavelength equal to the Compton wavelength of that particle.

4.0 PHOTON DOWN & UP-CONVERSION

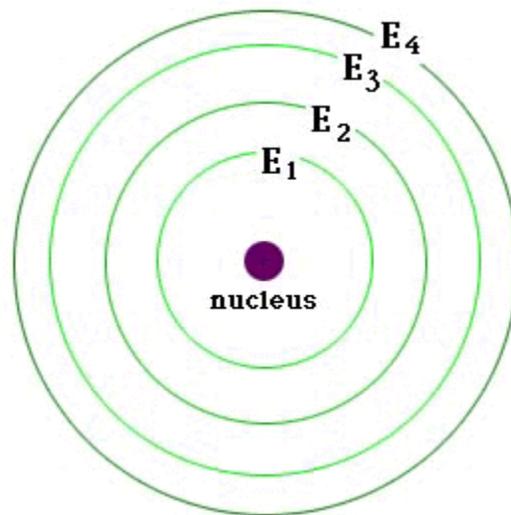
Down-conversion is a process wherein, under certain circumstances, a pulsed pump laser beam photon incident on a special non-linear optical crystal will output two correlated daughter photons. The polarization of each output photon is orthogonal to that of the other. The two, quantum entangled, output photons can have equal or unequal frequencies. For equal frequencies, the twin photons will have twice the wavelength and half the frequency (or energy) of the primary or parent photon.

Parametric down-conversion (PDC) is a non-linear process wherein, a light ray impinging on a non-linear crystal creates two new light rays, usually called signal and idler, obeying energy and momentum conservation. The signal and idler photons are perfectly correlated in energy (frequency), emission times, polarization and angular momentum (spin and orbital). The two photons (idler and signal) are always produced together. A circularly polarized photon carries a spin angular momentum. Polarization (clockwise or anticlockwise) enables only two photon spin states.

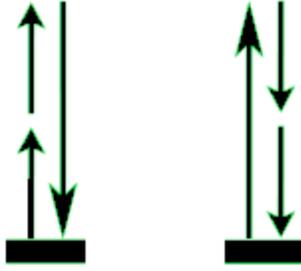
A photon down-converter is a device that splits a high-energy photon into two low-energy photons. When a photon reaches the down-converter, it excites an electron

into a higher energy level. But the electron returns to its ground state via an intermediate energy level, and emits a lower energy photon at each stage. Three-photon down-conversion is also observed.

An electron moves from one orbit to another by absorbing or emitting a photon. (See figure below). When it moves from a low energy ground state orbit E_1 to high energy excited state orbit E_4 it will absorb a high energy photon. The electron can return to its ground state in 2 or 3 steps by emitting 2 or 3 low energy photons, one at each stage. This is photon down conversion. A high energy photon splits up into 2 or 3 low energy photons in conformity with the law of conservation of energy and momentum. The reverse process is photon up conversion.



A down-converter is a special non-linear crystal that splits a single photon into two. A laser ray (pump-photons) passing a down-converter is split into a signal ray and an idler ray corresponding to signal-photons and idler-photons. Energy conservation requires that the pump-photon frequency be equal to the signal-photon frequency plus the idler-photon frequency. The signal frequency and idler frequency can be equal or unequal and depend on the angle the pump wave vector makes with respect to the crystal axis.



Photon up-conversion is a process which occurs when a material is photo-excited by two low-energy photons resulting in the emission of a higher energy photon. A converter seeks to either produce one high-energy photon from two low-energy photons (up-conversion) or, two low-energy photons from one high-energy photon (down-conversion).

Semiconductors with radiatively efficient impurities can potentially act as up or down-converters. A crystal of beta barium borate (BBO) can split an ultraviolet photon of wavelength 390 nm into two infrared photons of wavelength 780 nm. The two down-conversion photons have orthogonal polarization.

In the Sun, a gamma photon in the radiation zone, on its way to the photosphere, transforms into a hundred thousand visible light optical photons during its journey through the turbulent conduction zone.

The Evans photomagnetron has all the known properties of magnetic flux density (Tesla = Weber per square meter). If a low frequency photon is an atom of magnetism then a high frequency photon is a molecule of magnetism.

Jacobson et al [15] have in 1995 shown theoretically that the de Broglie wavelength for an ensemble consisting of (N) entangled photons, each with a wavelength (L), would be (L/N). A collection of (N) entangled photons with frequency (f), behave as a single entity with frequency (Nf).

This proposition was verified experimentally in 2002 for the case of two entangled photons by Edamatsu et al [16]. The two photons behave as if they acted as a single entity with a wavelength half that for either photon alone. In 2004 Walther Philip et al [21] have shown that the de Broglie wavelength of a four-photon state is one fourth of a single photon.

5.0 PLANCK PHOTONS, DARK PHOTONS & ZERO POINT PHOTONS.

The photon frequency available is continuous and has no upper or lower bound. There is no finite lower limit or upper limit on the possible energy of a photon. However, going by observations, the most energetic photons are the cosmic gamma photons with a wavelength of 10^{-15}m . The least energetic are the Very Low Frequency (VLF) radio photons with a wavelength of 10^5m .

- **PHOTONS** can be classified as per their wavelength:
 - *Radio* photons 10^5 to 10^{-1}m .
 - *Microwave* photons 10^{-1} to 10^{-3}m .
 - *Infrared* photons 10^{-3} to 10^{-6}m .
 - *Optical* photons 10^{-6} to 10^{-7}m .
 - *Ultraviolet* photons 10^{-7} to 10^{-9}m .
 - *X-ray* photons 10^{-9} to 10^{-11}m .
 - *Gamma* photons 10^{-11} to 10^{-13}m .
- *Theoretically, the most energetic photon that can exist in the universe will have a wavelength equal to the Planck length ($1.6162 \times 10^{-35}\text{ m}$) and possess Planck energy. One can call this a **Planck photon**.*
- *And, a photon with the least energy will correspond to a photon with a temperature*

*close to zero kelvin. This can be termed as a **zero point photon (ZPP)**.*

The cosmic zero point photons (ZPP) are a constituent of the vacuum energy of free space and the spacetime fabric of the cosmos. A vacuum, strictly speaking, is a physical state totally devoid of particles of matter or of radiation (photons). Such a vacuum does not exist in practice.

In comparison, a CMB (cosmic microwave background) photon has a temperature of 2.7 K, a wavelength of 1.1mm and the density is 411 photons per centimeter cube.

***DARK PHOTONS.** Photons with frequency or energy more than gamma and less than Planck photons can be called dark photons. They may be the particles of the elusive dark matter.*

*A black hole will consist mainly of Planck and dark photons. **A Planck photon will emit MeV, GeV or TeV gamma photons and transform into PeV, EeV, ZeV or YeV dark photons.***

Ordinary matter is matter that emits or reflects radiation, which is, radio waves, microwaves, infrared, visible light, ultraviolet, x-rays or gamma rays.

An electron is indivisible but a photon can split and also join with another photon. If, the Lorentz electron is an “atom of electricity” then, the Evans photon is a “molecule of magnetism”.

Einstein understood that photons are a mass-energy transfer mechanism. The emission (or absorption) of a photon by an electron, results in a decrease (or increase) in the mass-energy of the electron.

The photon has several properties that distinguish it from all other subatomic particles. It is the only elementary particle wherein a high-energy photon can transform /split into two or more low-energy photons (down-conversion) and vice versa (up-conversion). This transformation conforms to the laws of conservation of momentum and of energy.

The Evans photomagneton or the longitudinal magnetic field of a photon also has to be conserved. If, for example, a visible-light photon (wavelength 405 nm) splits up into two infrared photons (wavelength 810 nm), then, the photomagneton value of the visible light photon has to be equal to the sum of the photomagneton values of the two infrared photons. This implies that the photomagneton value is inversely proportional to the photon wavelength or directly proportional to the photon frequency.

6.0 PAIR PRODUCTION AND ELECTRON-POSITRON ANNIHILATION

Pair production is the simultaneous formation of an electron and a positron from a gamma photon with energy in excess of 1.02 MeV. A gamma photon with sufficient energy can be transformed into a real electron-positron pair. Pair production is direct conversion of radiant energy to matter plus anti-matter. Also, an electron and a positron annihilate each other, to produce two gamma photons each of 0.511 MeV, in almost exactly opposite direction to conserve momentum.

- *A photon is the common denominator of all energy, matter and anti-matter in the universe. All energy is electromagnetic in nature and, all mass and charge are electromagnetic in origin.*

7.0 PHOTON STRING THEORY

STRING THEORY is a theory of subatomic particles and fundamental forces of nature. The theory replaces point

like elementary particles by one-dimension strings. Open strings have free ends and closed strings form loops. Elementary particles are strings vibrating in different modes. Mass and charge are different manifestations of the same basic string.

The emission of a photon by an electron is the splitting of a string into two strings. The absorption of a photon by an electron is the joining of two strings into one. Interactions in string theory occur by joining and splitting of strings. In pair production, a photon-string splits up into two strings, with the vibration pattern of an electron-string and a positron-string; and vice versa in electron-positron annihilation.

The first suggestion of string theory was made by PAM Dirac in 1950. Yoichiro Nambu proposed his string theory in 1970 [9]. Nambu's strings are massless, vibrating, oscillating, rotating, one-dimension objects, which are free to split or join, and move at the speed of light. The strings create their own dynamic spacetime rather than simply moving in some background space. Superstring theories involve the idea of higher dimensional spaces; ten dimensions for fermions and 26 dimensions for bosons.

“In string theory, different harmonics correspond to different elementary particles. All elementary particles – electrons, neutrinos, quarks, etc., - owe their existence to subtle differences in the vibrations of strings. The theory offers a way to unite disparate particles because they are, in essence, different manifestations of the same basic string. Strings may be open ended or closed loops. In string theory, elementary particles are not points but vibrating strings. The frequency of the string determines what type of particle it is”. Ed Witten [7].

- *String theory is a mathematical model in need of a physical model.*

- *A string is a standing wave photon moving (vibrating, oscillating, rotating, spinning, twisting, turning) in a SHM. One may call the “string theory” as a “**photon string theory**” so as to reflect on its true physical nature.*
- *The linear momentum of a standing wave photon translates into the mass of a subatomic particle. And the rotational momentum of a standing wave photon translates into a positive or a negative charge of the subatomic particle depending upon the rotation being clockwise or anticlockwise.*
- *The law of conservation of linear momentum translates into the law of conservation of mass. And the law of conservation of angular momentum translates into the law of conservation of charge.*
- *Linear and angular momentum are independent of each other. Neither momentum can be transformed into another.*
- *Similarly, mass and charge are independent of each other. One cannot be transformed into another. However, both mass and charge derive their origin from a photon.*
- *Also, the force of attraction between two point masses is an inverse square law and so is the force of attraction or repulsion between two electrically charged particles.*

The different SHM vibration, rotation and oscillation patterns (linear, elliptical or circular) of the magnetic dipole, the photon, create their own dynamic electromagnetic spacetime. The photon motion, correspond to and create the different masses and force charges (electromagnetic, strong and weak nuclear interactions) of the various elementary particles.

This physical model of the string theory explains the original string theory idea that an elementary particle is an (electromagnetic) standing wave. It also interprets: Edward Witten's [2] view that "an electron is a little vibrating string"; Michael Green's [2] comments that "*the strings vibrate not only in space but also in time*"; "*the spacetime, in which the string is moving, is itself altered by strings*"; and the additional dimensions are "*not really dimensions at all*" [9].

The additional dimensions in string theory do not relate to 4D spacetime but to force charges; just as in the 5D Kaluza-Klein theory the fifth dimension refers to Maxwell's electromagnetic field. And, the Calabi-Yau spaces can be thought of as generalized Kaluza-Klein 6D spaces.

As explained in #2.1-2.3, an electron, proton or a neutron exhibits non-thermal, SHM, standing wave, intrinsic electromagnetic inertia, resonance Compton frequency oscillations in its own rest frame. This can be linear, elliptical or circular.

Similar to the electron, proton or the neutron; the transverse magnetic (H) and electric (E) fields of a photon are orthogonal and in phase quadrature. The magnetic field energy plus electric field energy is always a constant. This contributes to the electromagnetic inertia,

SHM oscillations (linear, elliptical or circular) of the photon.

Williamson and van der Mark [19] have explored the possibility that an electron is probably a photon moving in a toroidal topology. This corresponds to a closed string and explains John Schwarz's [2] notion as to why "closed string theories look the most promising", and Edward Witten's [2] observation that, "most string theories have only closed strings". Also, the string (that is a photon moving in one-dimension) is itself moving in a helical path and tracing out a two-dimension surface or a membrane.

8.0 INTRINSIC SPIN & ORBITAL ANGULAR MOMENTUM

Subatomic particles carry energy and angular momentum. Angular momentum has two components: spin angular momentum (SAM) and orbital angular momentum (OAM). The SAM of the earth gives us day and night. The OAM of the earth gives us the seasons, as the earth moves around the sun. Spin is a fundamental property of subatomic particles. It is a quantum mechanical property and is present both in moving and in particles at rest. OAM results from the motion of a particle around some object, like an electron around a nucleus.

Spin is the intrinsic angular momentum of a particle which exists even when the particle is at rest (no linear motion), as distinguished from the orbital angular momentum (OAM). An electron has an intrinsic angular momentum and an intrinsic magnetic moment or spin. The observed electron spin angular momentum, implies that the electron is a tiny magnet.

Intrinsic spin does not imply that a subatomic particle is spinning like a toy-top about its axis. Spin corresponds to the circular or elliptical oscillations of a subatomic particle. An analogue in classical mechanics is the

“conical pendulum”. In subatomic particles, the intrinsic spin angular momentum is quantized. It always comes in fixed discrete units that are integer multiples of $\frac{1}{2}(\hbar)$. For ease of expression, a particle with spin $\frac{1}{2}(\hbar)$ is referred to as having ‘spin $\frac{1}{2}$ ’. Also, the electric charge is quantized and comes in simple multiples of the fundamental unit of electron charge.

The intrinsic spin of an electron and a photon have only two quantum mechanical states. For an electron this refers to spin-up or spin-down, that is, clockwise or anticlockwise oscillations. For a photon it corresponds to clockwise or anticlockwise, circular or elliptical polarization and the photon’s magnetic polarity, that is, NS or SN. The photon’s longitudinal $B(3)$ field is directly proportional to the spin angular momentum [6].

Photons have a spin angular momentum quantum number of 1. For the electron the SAM is $\frac{1}{2}$. Photons carry both spin and orbital angular momentum (OAM). Photon OAM has an infinite number of quantum mechanical states.

A photon is a boson with an intrinsic spin of 1. A photon (NS or SN) if rotated in space through 360 degrees will return to its original configuration. A proton or a neutron is a fermion with an intrinsic spin of $\frac{1}{2}$, and has to be rotated through 720 degrees before it returns to its starting configuration. A proton or a neutron probably oscillates, tracing a “figure of 8” as in a Lissajous’ figure in a cathode ray oscilloscope. This corresponds to a rotation of 720 degrees.

9.0 De BROGLIE WAVELENGTH

French physicist Louis de Broglie in 1923 predicted that subatomic particles, like the electron, might exhibit wave properties like the photon. This was confirmed in the Davisson-Germer experiment in 1927.

The **de Broglie wavelength** of a subatomic particle (or a physical body) of mass m , moving with a velocity v , is equal to h/mv , where h is the Planck constant. The de Broglie wavelength of a tiny dust particle weighing one microgram and moving with a velocity of one millimeter per second is 6.6×10^{-12} angstrom.

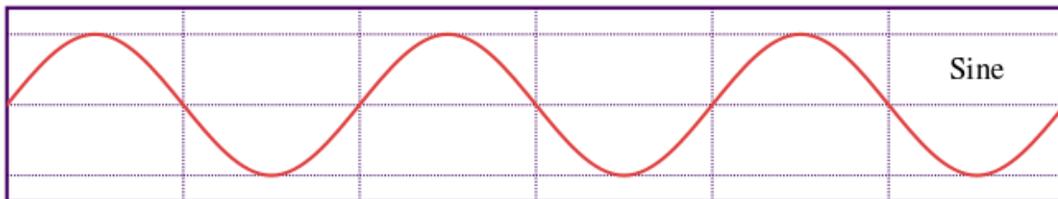
For heavier particles moving at higher velocities, the momentum mv increases and so, the wavelength h/mv decreases. The kinetic energy increases and so does the frequency. So, macro particles with their extremely small wavelengths do not seem to exhibit de Broglie or matter waves characteristics.

The de Broglie wavelength of the planet earth moving in an elliptical orbit around the sun can be calculated, and is 3.7×10^{-63} m; just as we can do so for an electron in a one-proton hydrogen atom. A particle at rest does not have a de Broglie wavelength.

10.0 WAVE MECHANICS AND REDSHIFT

A particle at rest at the origin in a given inertial frame of reference, when subject to a force in the (+) X-axis direction, will move with a uniform motion in a straight line in the (+) X-axis direction.

However, as explained in #2.1–2.4, a non-zero rest mass atomic or a subatomic particle, which is oscillating along the Y-axis, in a SHM, with its rest or fixed mean or equilibrium position at the origin; when subject to a force in the (+) X-axis direction at the origin, will move along a sine wave path in the XY-plane, in the (+) X-axis direction, even at relativistic velocities.



- *An atomic or a subatomic particle moves, not in a straight line but, along a sine wave path.*

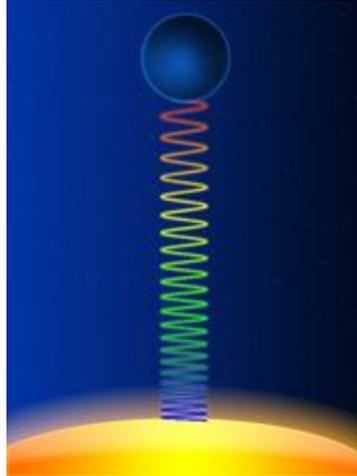
This explains the physical concept of wave mechanics. Matrix mechanics represents a tabulated form of wave mechanics.

An electron oscillates in a linear, elliptical or a circular orbit with a resonance Compton frequency mc^2/h , in its own rest frame. Twice the amplitude of this linear resonance oscillation is equal to the **Compton** wavelength h/mc . An electron moving with a velocity v will have a **de Broglie** wavelength equal to h/mv where, h is the Plank constant and m is the electron mass.

An electron exhibits a standing wave at the resonance Compton frequency mc^2/h , in the electron rest frame. A moving electron has a traveling wave with a de Broglie wavelength h/mv . *The **amplitude** of both the standing wave and the traveling wave is equal to one-half the **Compton wavelength**.*

The Compton wavelength (h/mc) is the shortest possible de Broglie wavelength (h/mv) as the particle velocity (v) approaches the speed of light (c).

- Since, a photon always moves with the speed of light, so:
For a photon, twice the amplitude (Compton wavelength) is always equal to the photon wavelength (de Broglie wavelength).
- *The light intensity does not depend on the square of the amplitude but is proportional to the photon flux density, as per Einstein's correlation of the number of photons in a light beam with its intensity.*



- *This also implies that a photon redshift is not a Doppler effect. Redshift is observed when a photon moves from a stronger to a weaker gravitational field. The photon undergoes down conversion. This is similar to an electron emitting a photon when it moves from a high energy excited state orbit to a low energy ground state orbit.*
- *Blueshift occurs when a photon moves from weaker to a stronger gravitational field. The photon undergoes up conversion by combining with a low frequency radio or zero point photon so as to be in equilibrium with its new spacetime curvature or the photon energy momentum density.*
- *Spacetime is an ideal photon gas consisting of Planck photons, dark photons, gamma photons, X-ray photons, ultraviolet photons, visible light photons, infrared photons, microwave photons, radio photons and zero point photons. The statistical distribution of*

these photons will depend on the spacetime curvature or the photon energy momentum density.

An electron is a particle but its motion is described by wavelike principles. Photons propagate through space in a wavelike fashion but display particle like behavior during emission and absorption. *An electron or a photon moves, not in a straight line but, along a sine wave path.*

- The wavelength (or twice the amplitude) of gamma and x-ray photons is in the range, 10^{-13} to 10^{-9} m, and so they behave more like particles moving in a straight line.
- For microwaves and radio waves photons, the wavelength (or twice the amplitude) is in the range, 10^{-3} to 10^5 m, and so they display more of wave like attributes.
- The wavelength (or twice the amplitude) of visible light optical photons is in the range, 10^{-7} to 10^{-6} m, and they exhibit dual wave-particle nature.

For 3 cm wavelength microwaves (linearly polarized), a wire-grid with a spacing of about 7-8 mm, roughly one-quarter of a wavelength; *the grid is completely transparent only when the wires are parallel to the transverse magnetic (H) field vector direction of the microwaves* [10].

- This shows that, *a photon oscillates in the transverse magnetic (H) field vector direction unlike the electron, which oscillates in the electric (E) field vector direction. Similarly, a proton oscillates in the electric (E) field vector*

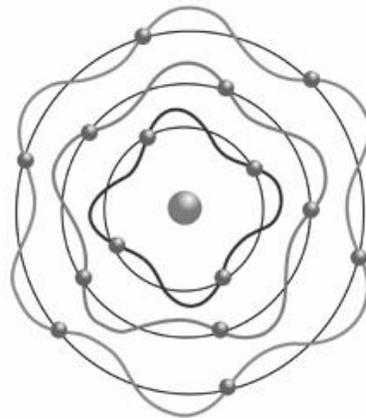
direction and a neutron oscillates in the magnetic (H) field vector direction.

11.0 ZITTERBEWEGUNG (ZBW)

A theory proposed by Schrödinger in 1930, zitterbewegung (zbw) is a German word for jitter motion. Zitterbewegung is a theoretical helical or circular motion of elementary particles, in particular electrons, presumed to be the basis of their intrinsic spin and magnetic moment. Zbw provides a physical interpretation for the complex phase factor in the Dirac wave function. Zbw is a real physical phenomenon and corresponds to a particle (*a photon*) going along a cylindrical helix, at the speed of light, in real space with a diameter equal to *Compton wavelength*. The zbw frequency is the electron *resonance Compton frequency*. David Hestenes [8] has written extensively on the zbw theory.

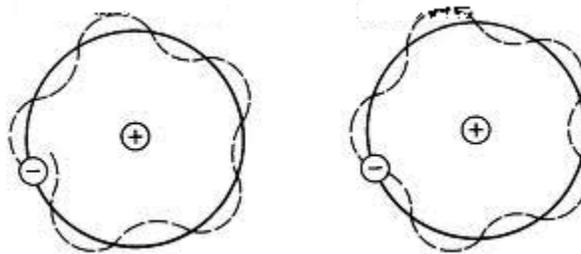
12.0 ATOMIC ORBITS

Since an electron does not move in a straight line but along a sine wave path, so, *electrons in atomic orbits do not move in a linear circular path but along a sine wave, circular path* [1]. The actual path is on a 2D orbital surface around the nucleus.



If, the electron orbit circumference is an integral multiple of the electron de Broglie wavelength; the electron which

is moving in a sine wave circular path, will repeat the same sine wave path in each successive orbit. The sine wave paths in consecutive orbits will exactly overlap. The electron wave reconnects with itself. *The electric (E) and magnetic (H) fields oscillate in space and time but do not travel in space and time. This is a stable standing wave electron orbit.* The orthogonal E and H fields are in phase quadrature.



Not a Standing Wave

Standing Wave

If, the electron orbit circumference is not an integral multiple of the electron de Broglie wavelength, the sine wave paths in successive orbits do not overlap. The electron wave does not reconnect with itself. The electric (E) and magnetic (H) fields travel in space and time along the electron orbit circumference. It is not a standing wave and so is an unstable electron orbit.

13.0 BOSE-EINSTEIN CONDENSATION (BEC)

In 1924, Indian physicist Satyendra Nath Bose, re-derived the black-body radiation spectrum by treating the radiation field as a gas of identical particles of photons, that is, a photon gas. Bose statistics show how a collection of photons are distributed among various energy states at a given temperature. The theory of the statistical mechanics of photons allowed a theoretical derivation of Planck's law.

Einstein argued that if the photon gas obeyed the statistics of Bose, so should material particles in an ideal gas. Einstein generalized *Bose statistics* into *Bose-*

Einstein statistics for an ideal gas of boson atoms and predicted in 1924, *Bose-Einstein condensation* (BEC) of boson atoms in the ground state at very low temperatures in the nanokelvin range. Einstein realized that an ideal gas of bosons would form a condensate at low enough temperature, unlike a classical gas. A BEC is a state of matter formed when a gas of bosons is cooled below a certain critical temperature. The first BEC with super cooled rubidium atoms was created in 1995.

Solid, liquid, gas and plasma are the four physical states of matter. BEC is the fifth state of matter beyond solids with a density more than the solid state.

At room temperature the de Broglie wavelengths of the atoms in a gas are 10,000 times smaller than the average spacing between the gas atoms. *BEC is a gaseous superfluid phase formed by atoms cooled to a point where the thermal de Broglie wavelength is comparable to the mean inter-atomic separation.*

At very low temperatures, in the nanokelvin range, the de Broglie wavelength of the atoms can be comparable to the mean distance between the atoms. The wave of one atom overlaps with that of the neighboring atoms causing them to lose their separate identity. The individual waves merge together, lock into, and end up in the same wave function, resulting in a single coherent quantum state.

BEC is a new form of matter. In a BEC every atom must move in the same manner, at the same time. *Coherence is the defining criterion for the BEC phase.* BEC is a coherent cloud of atoms, all in the same quantum mechanical state. In a BEC the atoms are all perfectly in phase, in the same energy state, as compared to the randomly moving atoms in a gas.

An essential property of BEC is macroscopic phase coherence. The wave function, of all the atoms in the condensate, consists of a superposition of identical wave functions. The wave function, of the macroscopic quantum state, remains coherent for a number of bosons. BEC is a blend of atoms acting in unison with their motion identical to one another.

The individual atoms overlap each other and coalesce into a *super atom*, described by one single wave function exactly as in a single atom. *A super atom is a collection of coherent atoms merged into a single dense entity, and behaves like an individual atom. BEC of millions of atoms, a few millimeters across with a density of 10^{14} atoms/cc have been created, and behave as one giant coherent atom.* The atoms can all be regarded as having the same single particle wave function with 99% accuracy, even for the interacting gases. A BEC is a cold dilute cloud of atoms that scatters light as ordinary atoms do.

Creating a BEC is simple in principle. Cool a gas until the thermal de Broglie wavelength is roughly the same as the distance between the atoms. The challenge was to cool the gases to temperatures around or below one micro-kelvin, while preventing the atoms from condensing into a solid or a liquid. In almost all cases, the BEC phase transition is pre-empted by the more familiar phase transitions that lead to liquids or solids. BEC in atomic gases can only be achieved using extremely dilute gases, so that BEC can be achieved in what is essentially a meta-stable gaseous phase.

A BEC results when an atomic vapor of bosons is cold and dense enough, so that the inter-atomic spacing approaches the thermal de Broglie wavelength. Laser trapping and cooling can slow atoms to very small

velocity spreads, so that their de Broglie wavelength corresponds to the average inter-particle separation.

In quantum optics an ensemble of photons is treated as a *Bose condensate* which has a de Broglie wavelength given by L/N where L and N are the wavelength and average number of constituent photons, respectively [15]. A collection of (N) entangled photons with frequency (f), behave as a single entity with frequency (Nf).

14.0 ELECTRON PHYSICAL MODEL

- *“I would be happy just to know what an electron is”.*

Albert Einstein (1950’s).

In reply to the ever increasing number of subatomic particles which were being found using high energy accelerators.

Mathematics is the language of physics. A phenomenon in physics can be explained by different mathematical models. But, there can be only one physical model for a comprehensive understanding of the phenomena. All mathematical models of the electron must conform to the same physical reality.

The ring model of the electron was first suggested by Alfred L Parson in 1915. Bergman and Wesley [17] in 1990 developed the spinning ring model of the electron wherein, the electric charge on the ring surface rotates at the speed of light. The size of the electron equals the *rationalized Compton wavelength*, and the frequency of rotation equals the *Compton frequency*.

Williamson and van der Mark [19] in 1997 have proposed that *an electron may be a photon moving in a toroidal topology*. The authors discuss the possibility that a bound (standing wave) photon state may give rise

to an electric monopole. “If the electron is indeed constituted by a photon, other elementary particles may also be composed of photon states, but in some other configuration” [19].

“Muons and tauons may be formed by electron-like states with a different internal curvature” [8]. A muon is an elementary particle identical to the electron in every way except mass. The muon having 207 times the mass of the electron, can be thought of as an extremely heavy electron. Ganthier [20] describes a helical model for the electron.

A photon based model of the electron, explains the emission or absorption of a photon by an orbiting electron in an atom, when changing orbits. The electron mass-energy changes due to loss or gain of a photon. This results in a change in the electron de Broglie wavelength and enables the electron to continue to be a stable standing wave in its new orbit.

This electron physical model seeks to unify three different schools of thoughts in physics; the Evans photomagnetron concept with the zitterbewegung and the *photon* string theory.

15.0 INTERFERENCE

First a conceptual picture of what happens to photons traveling through a single slit is given, followed by an explanation of two-slit interference.

15.1 SINGLE SLIT

Imagine seven horizontal parallel rays of light traveling in the (+) X-axis direction, in a horizontal XZ-plane; through a vertical slit (Y-axis) with a slit width of 7-wavelengths (from $Z = - 3.5$ to $z = + 3.5$).

- Let the rays be numbered from **#1** to **#7** with ray **#4** in the middle (X-axis).

- Rays **#3, #4 & #5** ($Z = -1, 0$ & $+1$) will travel straight through the slit onto the screen.
- Rays **#1 & #7** ($Z = -3$ & $+3$), being close to the slit walls, will experience diffraction due to elastic scattering since; the photons are traveling along a sine wave path and not in a straight line.
- Photons traveling along rays **#2 & #6** ($Z = -2$ & $+2$) will experience some diffraction due to elastic scattering of photons in the neighboring rays **#1 & #7** ($Z = -3$ & $+3$).

15.2 TWO SLIT INTERFERENCE

Figure 1, represents eight photons of *unpolarized* light traveling along a horizontal ray in the (+) X-axis direction. Neighboring photons have opposite magnetic polarity; so, *unpolarized* light does not exhibit magnetism on interaction with matter. Also, the polarization of neighboring photons is orthogonal. In an *unpolarized* ray, any two neighboring photons are correlated and form a quantum entangled pair.

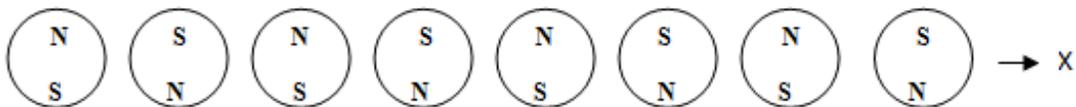


Figure 1

Figure 2 below represents 8 vertical (Y-axis) parallel coherent rays of un-polarized light in the XY plane, traveling in the (+) Y-axis direction. Each ray has 4 photons. In a coherent beam all rays are in phase. Photons in any parallel XY plane, the magnetic polarity is such that unlike magnetic poles, in any two neighboring XY planes, face each other, and so attract each other. Photons thereby, exhibit a bunching tendency, a property shown by all bosons.

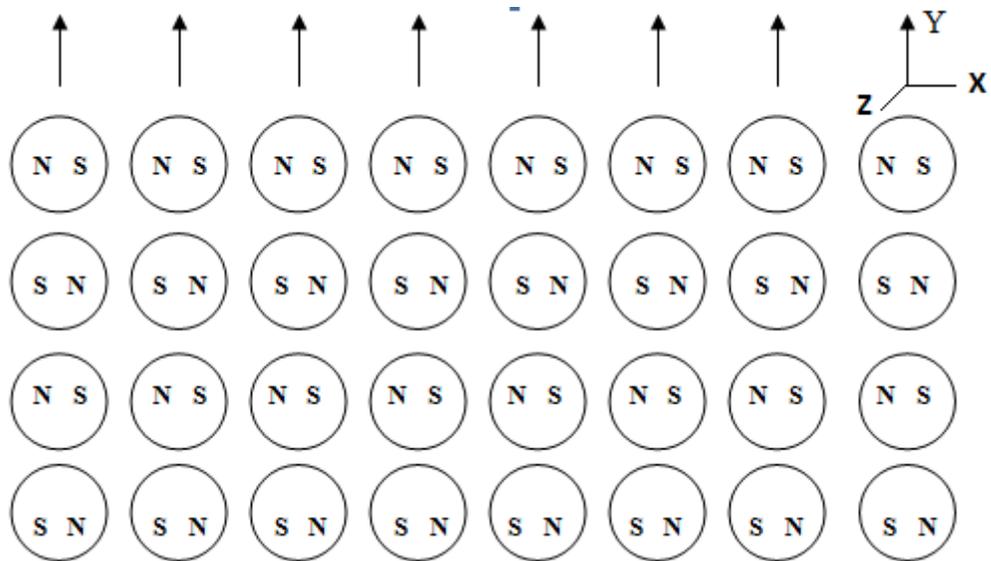
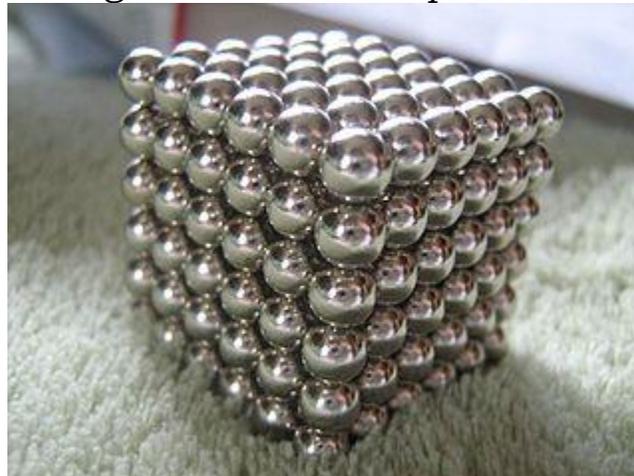


Figure 2

Below is a 3D representation of a 2D photons arrangement in the XY plane above.



<http://en.wikipedia.org/wiki/File:NeoCube.jpg>

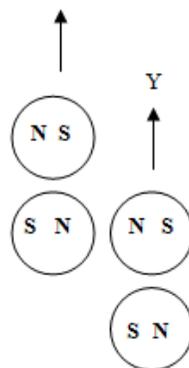
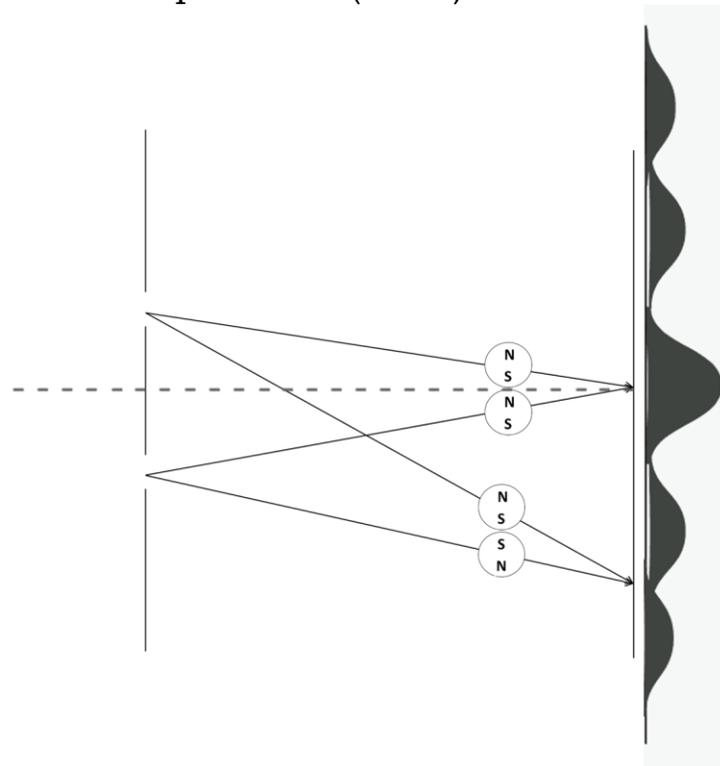


Figure 3

Figure 3 above, represents two rays of un-polarized light, traveling in the (+) Y-axis direction. Each ray has two photons, as shown. The two adjoining photons are out of phase by 180 degrees. These two adjoining photons will repel each other since, like magnetic poles repel each other.

In a double slit interference experiment, coherent photons after being diffracted and traveling from the two slits towards the screen, along two convergent rays of light; if on arrival at a point on the screen, are out of phase by 180 degrees, will repel each other and get deflected to neighboring areas, thereby creating a dark band between two bright neighboring bands. This explains Thomas Young's interference experiment (1801).



In the Figure above, along the dotted center-line of the screen, there is a high photon intensity region as the 2 photons are in phase and attract each other. Whereas, in the lower part of the screen the 2 photons are out of phase by 180 degrees and so

repel each other and get deposited in neighboring areas, thereby resulting in a dark or very low photon intensity region between two neighboring bright or higher photon intensity regions.

16.0 HANBURY-BROWN & TWISS (HBT) EXPERIMENT

It is reported that two-slit interference occurs even when the intensity is reduced so much that only one photon or electron traverses the apparatus at a time.

However, Robert Hanbury-Brown and Richard Q. Twiss have observed in their experiment (1956) that photons, in a coherent beam, are not emitted one at a time at equal intervals. *Photons or electrons in a coherent beam, travel in bunches or groups and not as separate individual particles at equal intervals.* The HBT experiment has been well explained by Akira Tonomura [14].

Two interference patterns (formed by a low intensity beam and a high intensity beam) will be identical for an equal number of photons. The time taken to form will be different. The interference pattern is related to the number of photons striking the screen. The basic requirement for interference is a coherent beam of photons or electrons. *Coherence is the defining criterion for interference.*

In the case of Newton's rings, the incident light beam may not be coherent. Each ray of light in the beam is partly reflected at the glass/air and partly at the air/glass interfaces. The two reflected rays are *self-coherent* and interfere constructively or destructively. The interference gives dark and light concentric rings with monochromatic light and rainbow colors ring pattern in white light.

17.0 ELECTRON INTERFERENCE

Electrons are fermions and obey the Pauli exclusion principle. Electron pairs have zero spin and behave like bosons. Vacuum or free space temperature is a few degrees above zero kelvin. Electrons in a coherent beam in free space move in pairs, just as they do in a superconductor at temperatures near zero kelvin. This bosonic behavior explains electron interference.

In an electron-ray neighboring electrons have opposite intrinsic spin (up or down); just as in a light ray neighboring photons have opposite magnetic polarity (NS or SN) as shown in Figure 1 in #15.2. In a coherent electron beam neighboring electrons in adjoining rays have opposite intrinsic spin (up or down); just as in a coherent light beam neighboring photons in adjoining rays have opposite magnetic polarity (SN or NS). Electron interference is thus similar to photon interference as explained in #15.2

When we observe, as to which one of the two slits the electron is traveling through, we disturb the coherence in the electron beam and so the interference does not occur. *Coherence is the defining criterion for interference.*

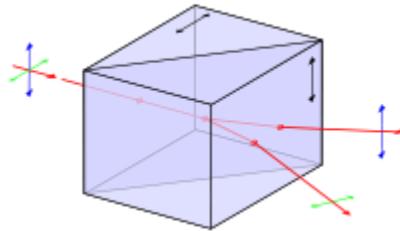
18.0 POLARIZATION

Polarization is of three types: linear, circular and elliptical. Elliptical polarization includes the other two as special cases. Natural or ordinary unpolarized visible light has an appreciable bandwidth (VIBGYOR). It includes all three types of polarizations. The most prominent feature of unpolarized light is its constantly changing, predominantly elliptical, character [13].

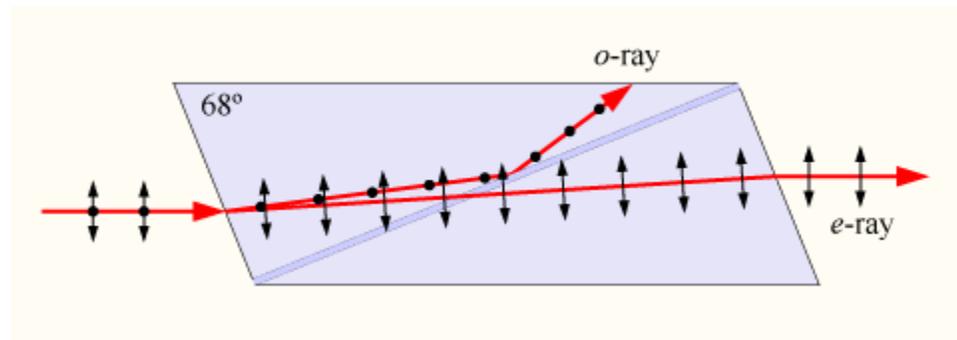
18.1 LINEAR POLARIZATION

A ray of unpolarized light, (see Figure 1 in #15.2), incident on a crystal of calcite (Nicol prism) or quartz (Wollaston prism); adjoining photons with opposite magnetic polarity (and orthogonal

polarization) travel along different paths through the crystal, resulting in two equal intensity rays of linearly polarized light with orthogonal polarization.



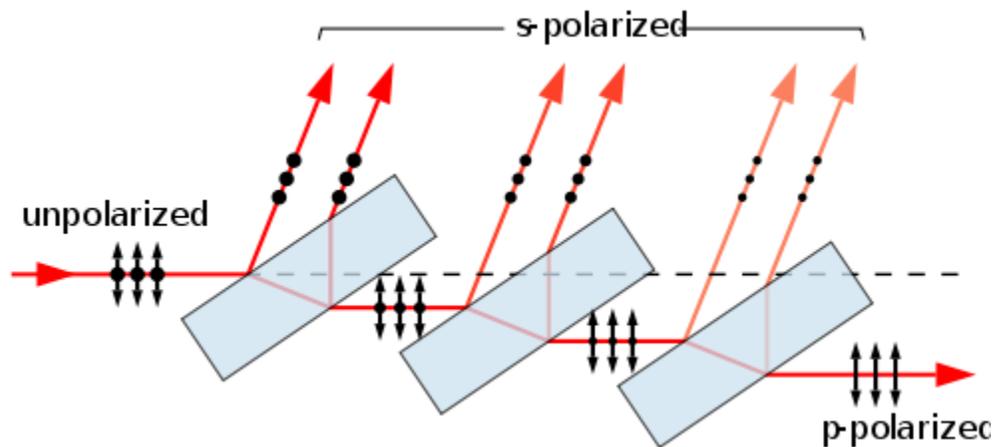
<http://en.wikipedia.org/wiki/File:Wollaston-prism.svg>



<http://en.wikipedia.org/wiki/File:Nicol-prism.png>

Similarly, a ray of unpolarized light incident on a reflecting surface, at the Brewster angle; alternate photons of a given magnetic polarity (either NS or SN) are reflected at the surface. The remaining alternate photons (50%) with the opposite magnetic polarity (SN or NS) are transmitted in the case of a glass plate or, are absorbed in the case of a metallic mirror.

The equal intensity reflected ray and transmitted ray are both linearly polarized rays with orthogonal polarization. The reflected ray is polarized in the plane of incidence. Also, at the Brewster angle of incidence, the reflected ray is perpendicular to the refracted ray.



<http://en.wikipedia.org/wiki/File:Brewster-polarizer.svg>

- *The transverse magnetic field vector direction of polarization of photons traveling along a ray of linearly polarized light is not confined to a single plane of vibration, but has an angular spread of 90 degrees [12].*

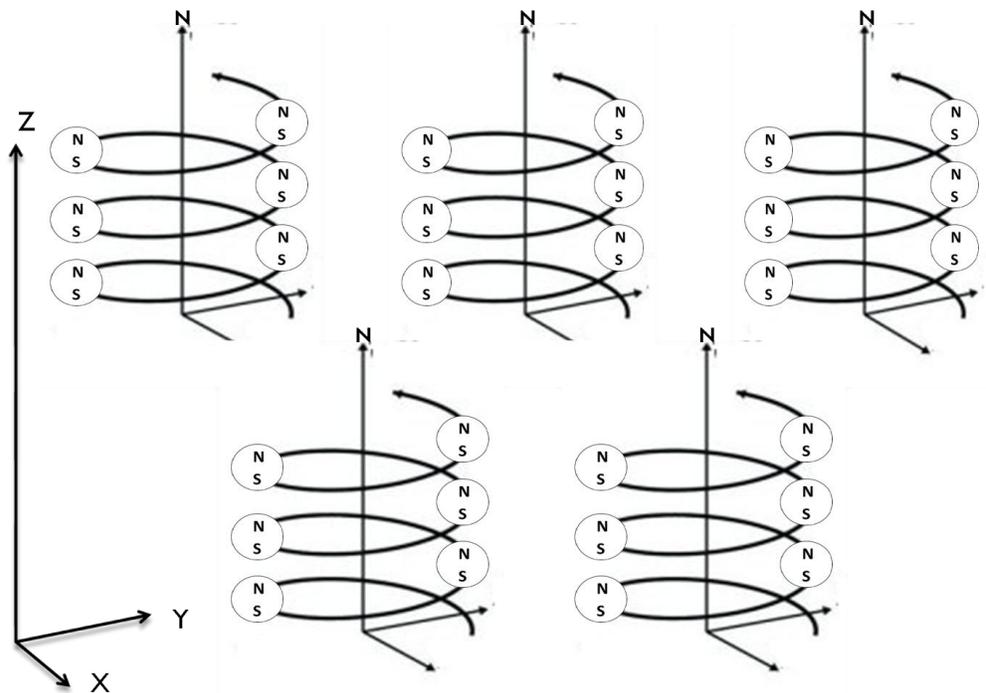
18.2 CIRCULAR POLARIZATION

Frenchman Francois Jean Arago experimentally discovered circular polarization in quartz in 1811. In circular polarization the transverse magnetic (H) and electric (E) field vectors rotate rather than oscillate as in linear polarization. In both cases the transverse magnetic (H) and electric (E) fields are orthogonal and in phase quadrature. The magnetic field energy plus electric field energy is always a constant. This contributes to the electromagnetic inertia, SHM oscillations of the photon.

In a ray of circular polarized light, photons travel along a circular (clockwise or anti-clockwise) helix or spiral path of wavelength diameter, or radius

equal to the amplitude. All photons in a ray have their magnetic polarity (NS or SN) parallel to the centerline of the spiral. The magnetic dipoles of all the circular polarized photons, add up to give a net resultant magnetic field along the centerline of the spiral.

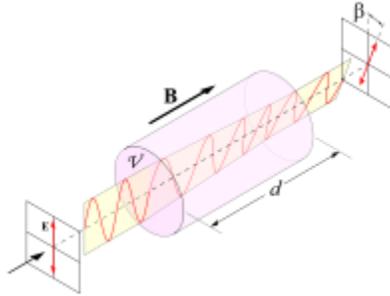
The figure below, shows a beam of light consisting of 5 rays of circular polarized light, all 5 rays are travelling in the +Z-axis direction. The magnetic dipole photons in each ray with their magnetic polarity NS along the Z-axis add up so that circular (or elliptical) polarized light acts as a magnet upon interaction with matter. This is the ‘inverse Faraday effect’ (IFE).



This also explains the ‘*optical Faraday effect*’ (OFE) and similar magneto-optical effects. The OFE is the rotation of the plane of polarization of a linear polarized probe beam by a second, circular polarized, pump laser. The latter substitutes for the magnetic field of the ordinary Faraday effect.

19.0 The FARADAY EFFECT

The Faraday effect or the Faraday magneto-optic rotation is the observed rotation of linear polarized light passing along a rod of very dense glass, or certain other substances, placed along the axis of a strong magnetic field.



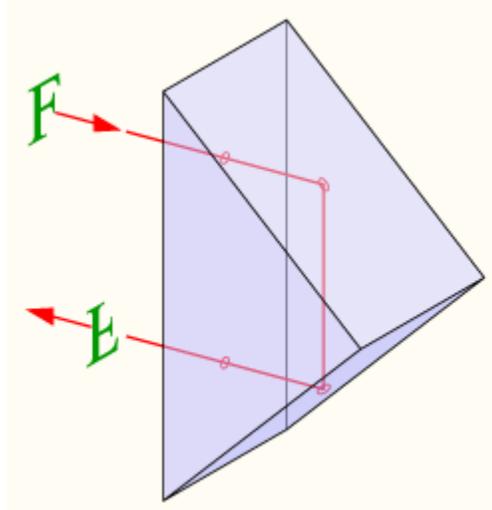
<http://en.wikipedia.org/wiki/File:Faraday-effect.svg>

If the rotated beam is reflected back towards the source, the rotation is not reversed on the return trip and thus cancelled out, but occurs again so that the rotation is doubled. This may seem paradoxical because light passing the opposite way in the same field is then being rotated the opposite way. David Pye [10] says that, “this shows, it is not the material of the glass, but the light ray (*photon*) has some directional property across its line of travel”.

Reflection of a photon at an air / glass interface involves a phase change of 180 degree or one-half a wavelength. The NS photon on reflection becomes a SN photon or vice versa and so does not reverse its path after reflection. When light in glass reflects from a glass / air boundary, there is no phase change since light is going from a more optically dense material (glass) to a less optically dense material (air).

In a right angle glass prism (90-45-45 degree), light will undergo double total internal reflection at the glass / air boundary inside the prism and bend the

incident light beam by $90+90=180$ degrees from its original trajectory with no phase change. The reflected light will retrace its original path.



<http://en.wikipedia.org/wiki/File:Porro-prism.png>

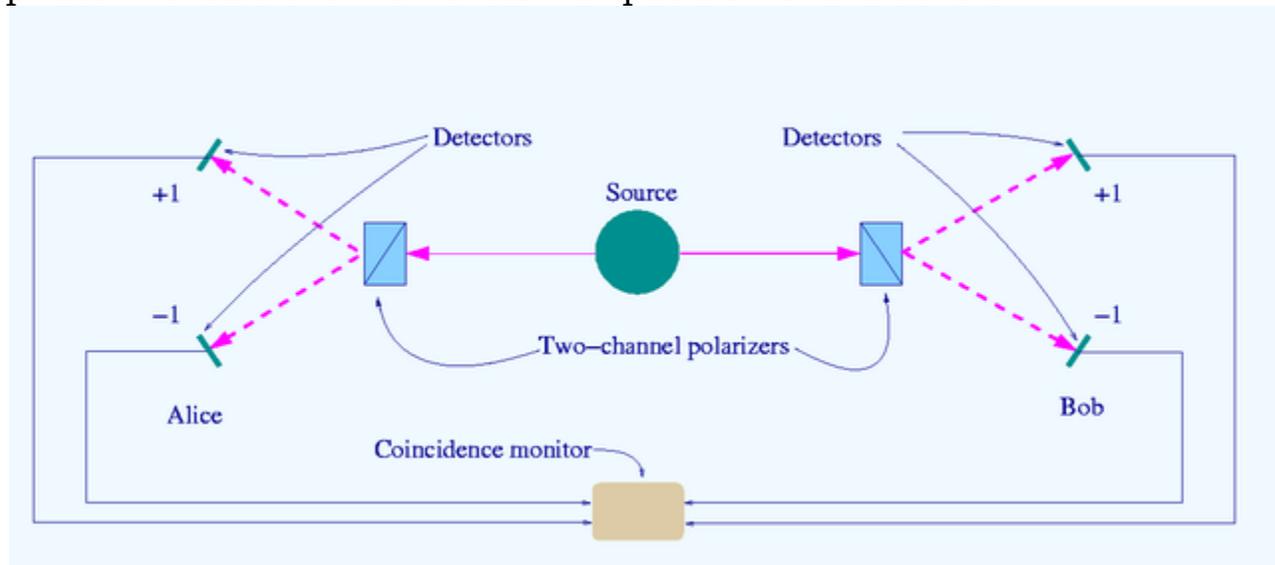
20.0 PHOTON'S MOMENTUM

Radiation pressure is exerted by unpolarized or linearly polarized photons in the direction of photon travel. This is due to the photon's linear momentum. In a similar manner a mechanical torque is produced by circular polarized photons. This was observed in an experiment by R A Beth in 1936 [13]. This is due to the photon's angular momentum. Both the linear and angular momentum effects of the photon are mechanical in nature and exhibit the particle like behavior of the photon.

21.0 The EINSTEIN-PODOLSKY-ROSEN (EPR) PAPER

In a thought experiment published in a 1935 paper by Albert Einstein, Boris Podolsky and Nathan Rosen; the authors disagree with the Heisenberg uncertainty principle and concluded that Quantum Mechanics is not a complete theory of nature.

The experiment seeks to look at both the position and momentum of a quantum particle simultaneously [3]. If a photon source placed at the origin in a given inertial frame of reference emits a pair of photons, simultaneously in the opposite direction, say, along the plus (+) X-axis and the minus (-) X-axis direction; then, a measurement of either the momentum or position of one photon reveals the momentum or position of the other.



<http://en.wikipedia.org/wiki/File:Bell-test-photon-analyser.png>

Polarization has been adopted as a convenient means of studying EPR correlations. Any two photons (or electrons) that originate from a common source will possess a total spin of zero.

In an experiment (1982) by French physicist Alain Aspect, a radioactive calcium atom emits two correlated photons of random polarizations in the opposite directions. The photon polarizations are separately measured many meters apart. The left hand detector records random polarizations, correlated to the right hand detector's measurements [11].

The crucial test comes when the polarization measuring devices are oriented obliquely to each other [3]. However, the recorded observations are easy to explain if we note that *the transverse magnetic field vector direction of polarization of photons traveling along a ray of linearly polarized light is not confined to a single plane of vibration, but has an angular spread of 90 degrees* [12].

The magnetic polarity of either photon is opposite to that of the other. If the plus (+) X-axis direction photon polarity is NS then, the minus (-) X-axis direction photon polarity is SN, or vice versa. Either photon will maintain its polarity and polarization independent of the other unless acted upon by an external force to change it.

The two photons created by the same source are correlated and form a quantum entangled pair. As mentioned in #15.2, in a ray of unpolarized light neighboring photons are correlated and form a quantum entangled pair. They have opposite magnetic polarity and the polarization of neighboring photons is orthogonal.

22.0 SPACETIME

An event is something that happens at a definite point in space and at a definite time. Aristotle believed in absolute space. Galileo's law of inertia or Newton's first law of motion got rid of the idea of absolute rest. As per Galileo and Newton, uniform straight line motion is physically, completely indistinguishable from the state of rest. There is no local way of telling uniform motion from rest. Galilean relativity tells us that there is no absolute meaning to the 'state of rest'. *The nonexistence of absolute rest means that one cannot give an event an absolute position in space.*

Both Aristotle and Newton believed in absolute time, that is, the time interval between two events is the same for

all observers, moving or stationary. Einstein's relativity put an end to the idea of absolute time. *Time is not separate and independent of space, but is combined with it to form spacetime. Space and time are relative, not absolute. Only spacetime is observer independent.*

In Newton's 3D space, gravity is a force. In Einstein's 4D spacetime (Riemannian geometry), gravity is not a force. It is spacetime curvature or the photon energy momentum density. *The earth moves in a straight line path in 4D spacetime. But, it is seen to move in an elliptical orbit in 3D space.* This is because the mass of the Sun causes the curvature or compression of spacetime. The Sun is 1/3rd of a million times heavier than the earth and contains more than 99.8 percent of the total mass of the solar system.

A particle or an object '*at rest in space*' is moving or traveling through time; it is ageing. A particle moving with the speed of light in space is '*at rest in time*'. There is no passage of time at light speed. Since, a photon is always moving at the speed of light, it is always '*at rest in time*'.

- *Spacetime is an ideal photon gas consisting of Planck photons, dark photons, gamma photons, X-ray photons, ultraviolet photons, visible light photons, infrared photons, microwave photons, radio photons and zero point photons. The statistical distribution of these photons will depend on the spacetime curvature or the photon energy momentum density.*

The lifetime of an elementary particle increases with its speed as predicted by Einstein's relativity. Relativistic time dilation is observed for atmospheric muons. A muon traveling at 99% of the speed of light, will have a lifetime that is about seven times longer than a muon at rest. The muon is an elementary particle identical to the electron in every way except mass, the muon having 207 times the mass of the electron.

There are three kinds of pions or pi-mesons:
positively charged pi(+),
negatively charged pi(-) and
electrically neutral pi(0).

The masses of pi(+) and pi(-) are equal, and are 273 times the mass of the electron. The mass of pi(0) is 264 times that of the electron. Perhaps, one unit of electron or positron charge has some relationship with 9 units of electron mass.

23.0 BLACK HOLE MAGNETIC FIELD

Escape speed is the speed that an object must attain in order to escape from the gravitational field of an astronomical body. The square of this escape speed is directly proportional to the mass and inversely proportional to the diameter of the star or planet. For the earth, the escape speed is 11.2 kilometers per second.

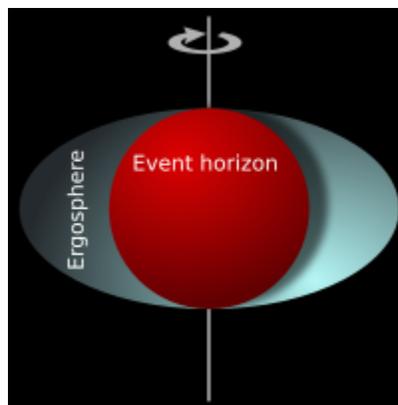
A black hole is a region of space or of spacetime within which the gravitational field has become so strong that neither particles nor photons can escape from it. It is a sufficiently massive body for which the escape speed exceeds the speed of light.

- *The internal structure of a black hole will consist of dark photons + Planck photons. In comparison, a neutron star interior is full of superfluid neutrons. It is a degenerate Fermi gas of neutrons.*

The size of a non-rotating stationary black hole depends only on its mass. If the Sun collapsed into a non-rotating black hole, its radius would be about 3 kilometers. For the earth it would measure 9 millimeters or less than a centimeter.

The surface of a black hole is called the event horizon and defines the boundary from inside which neither mass nor radiation can escape. Above the event horizon is the photon sphere. The photon sphere radius is about 1.5 times the event horizon radius. In a photon sphere, the photons orbit the black hole in circular orbits. A photon in equilibrium in a photon sphere can neither escape the black hole gravitational field nor is it pulled into the event horizon.

A non-rotating black hole is exactly spherical. This sphere constitutes the boundary of the black hole or the event horizon that does not let anything out. The structure of a rotating black hole is different from that of a stationary black hole. A rotating or a Kerr black hole is axially symmetric but not spherically symmetric.



All stars are known to rotate. The Kerr black hole rotates because the star from which it was formed was rotating, (conservation of angular momentum). Outside the event horizon of a Kerr black hole is the ergosphere within which matter is forced to rotate with the black hole. The

ergosphere is a solid ellipsoid, a 3D oval that floats above the event horizon of the black hole.

The ergosphere is in contact with the poles of the event horizon, and at the equator it has up to twice the diameter of the event horizon. The outer boundary of the ergosphere is called the static limit, so named because once inside this boundary, a particle cannot possibly be static or at rest relative to the distant stars. Black hole gravity is so strong that as it spins, it drags the surrounding space along.

At the event horizon the gravitation field tends to infinity. Our measuring rods shrink and tend to zero. Time slows down and almost stops at the event horizon. A black hole will take an infinite time to collapse beyond the mathematical boundary known as the 'event horizon'. It will take an infinite long time for the black hole to be crushed into a point of zero dimension known as a singularity. One may infer that singularities do not exist.

- *A black hole is not a spacetime singularity.*

Length contraction is compensated by time dilation.
When space distances shrink, time intervals lengthen, but spacetime is invariant.

A black hole will consist mainly of Planck and dark photons. *A Planck photon will emit MeV, GeV or TeV gamma photons and transform into PeV, EeV, ZeV or YeV dark photons.*

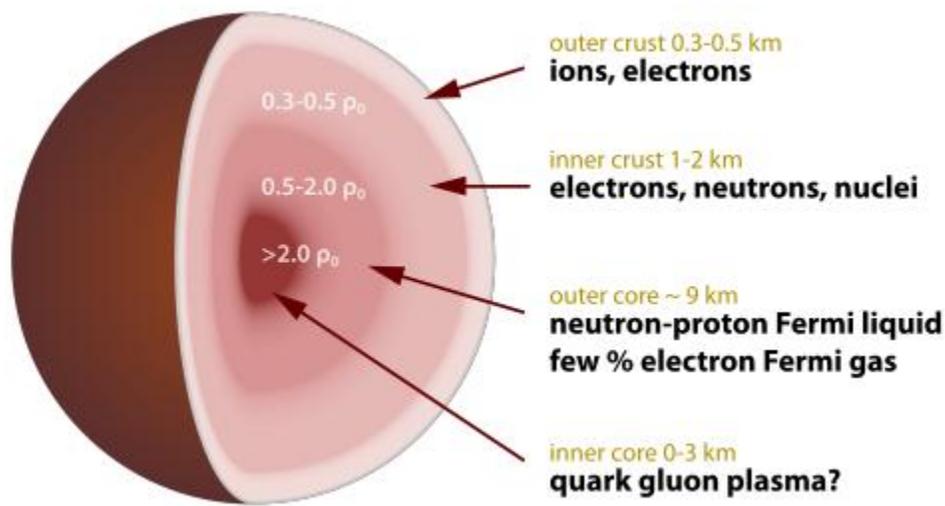
The photons, at or below the event horizon, arrange themselves in a 3D standing wave lattice, with unlike magnetic poles facing each other and so attracting each other.

A black hole, with a mass a few times that of the sun, would have a temperature of only a hundred nanokelvin.

- *Low temperature means low entropy which implies polarization. The circular or elliptical polarized dark and Planck photons give a black hole its magnetic field. The powerful magnetic field of super massive rotating black holes, of a million to billion solar masses, at the center of galaxies, is also due to the polarized (circular or elliptical) photons in the blackhole.*

24.0 NEUTRON STAR MAGNETIC FIELD

The mass of a neutron star is more than twice the solar mass. The higher the mass, the smaller is the radius. A typical neutron star is about 20 kilometers across. The density is about 10^{14} grams per centimeter cube, similar to that of an atomic nucleus. The interior is mainly densely packed superfluid neutrons. The surface gravitational field is about 70 billion times than that on Earth. The escape speed for a neutron star is one-half the speed of light.

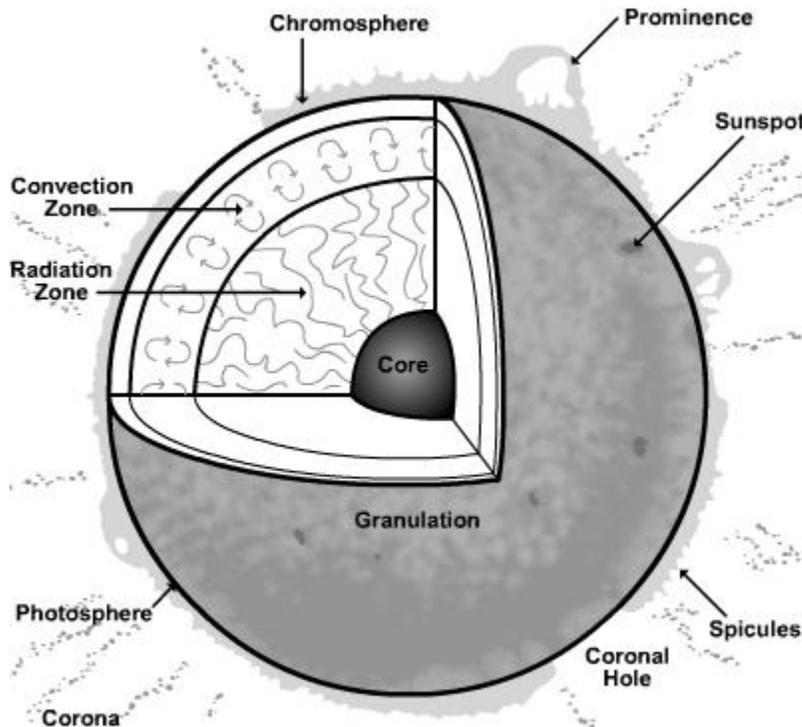


A neutron star is a degenerate Fermi gas of neutrons. It is a giant atomic nucleus, held together by gravitational rather than nuclear forces. The intense gravitational field of a neutron star is sufficient to crush the electrons and nuclei of ordinary atoms into matter consisting primarily of neutrons.

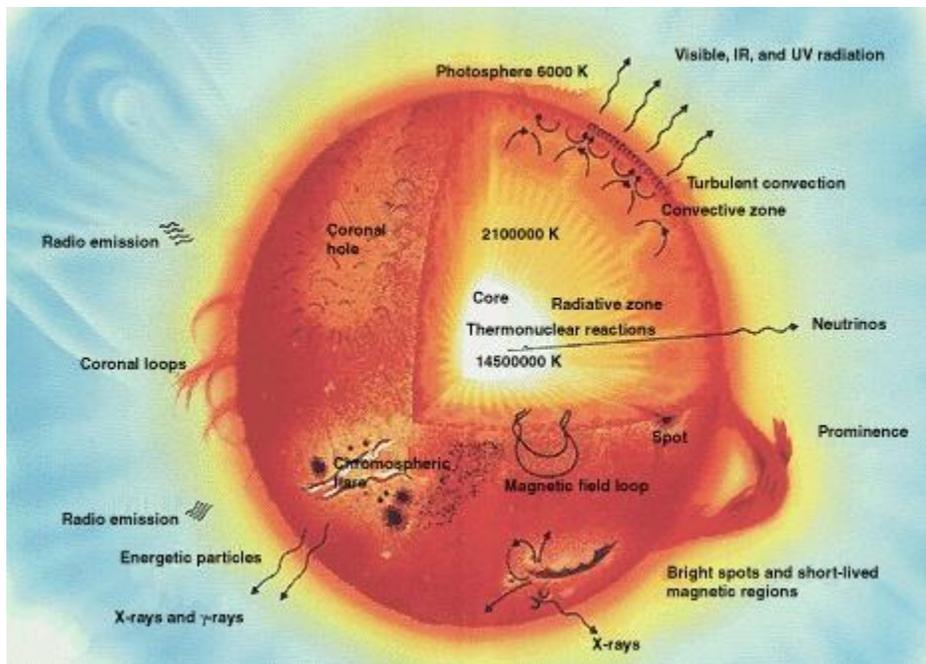
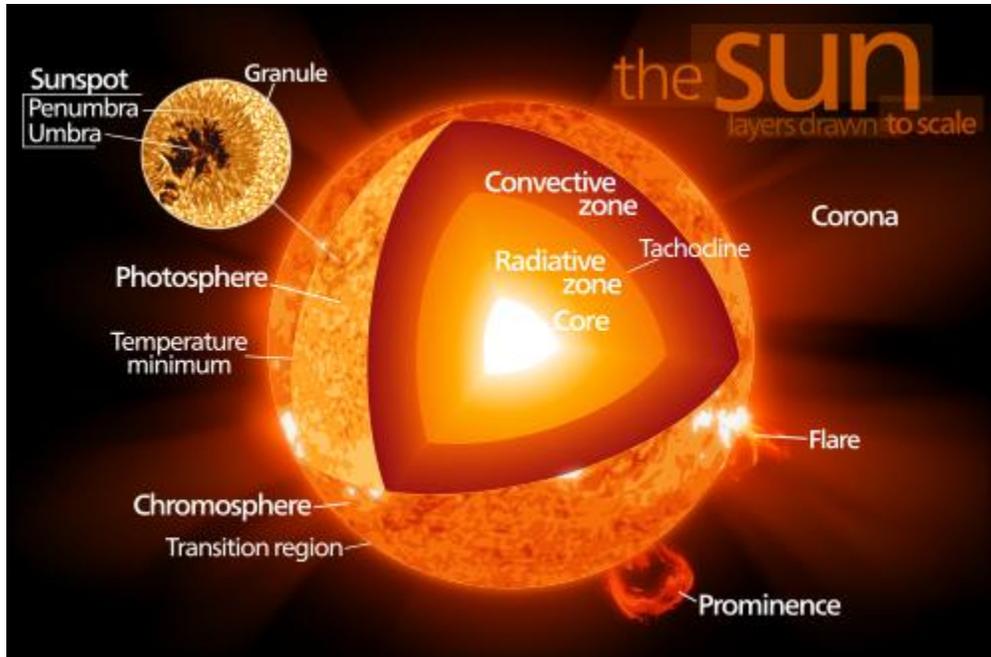
A neutron has zero electric charge but has an intrinsic magnetic moment; it is like a tiny magnet with a N-pole and a S-pole. In a stationary neutron star, the neutrons arrange themselves in a 3D lattice with unlike magnetic poles facing each other and so attracting each other.

- *In a rotating neutron star, the neutrons are polarized (circular or elliptical). This is the cause of a rotating neutron star's observed magnetic field of a billion to a trillion Gauss.*

25.0 SUNSPOTS'S MAGNETIC FIELD



The structure of the Sun consists of the central Core followed by the Radiation zone and the Convection zone. Next are the Photosphere and the Chromosphere near the surface; and the Corona, the atmosphere of the Sun, above the surface. The core contains about 40 percent of the Sun's mass in 10 percent of the volume. The escape speed for the surface of the Sun is 618 km/sec.



The radiation zone is a plasma of ionized hydrogen and helium atoms. It is from about 15 percent to 70 percent of the solar radius. The radiation zone density is 20 g/cc near the core and drops down to only 0.2 g/cc near the conduction zone. Photons from the core move in a zigzag fashion through the radiation zone towards regions of lower temperature and pressure.

It takes about a million years for a photon generated in the interior core of the Sun to travel through the radiation zone, and thereafter a month or so to travel through the turbulent conduction zone and reach the surface of the Sun. A high frequency *gamma photon* in the radiation zone, on its way to the photosphere, transforms into a hundred thousand lower frequency (visible light) *optical photons* during its journey through the turbulent conduction zone.

The photosphere, as the name implies, consists of photons of natural visible light, mostly unpolarized. It is sprinkled with small dark, relatively cool areas called sunspots, which are regions of strong magnetic field and always appear in pairs on the photosphere. Sunspot temperature is 4000 K compared to 6000 K elsewhere in the photosphere. Sunspot magnetic field is about thousand times stronger than the photosphere average. The two sunspots of a pair have opposite magnetic polarity.

- *Lower sunspot temperature means lower entropy which implies polarization, and so, sunspots are areas of polarized (circular or elliptical) photons, which explain their magnetic nature.*

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