"The most incomprehensible thing about nature is that it is comprehensible!"

ALBERT EINSTEIN

A POSSIBLE STRUCTURE FOR QUANTUM PARTICLES

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Abstract

In spite of its spectacular successes, Quantum Mechanics(QM) is still ridden with many problems especially with respect to its interpretation and the philosophical foundations which are hotly debated even today by many physicists. Among these we come across names of Albert Einstein, Schroedinger, Luis de Broglie, etc.

Notwithstanding the very impressive successes in the application of QM to many modern fields such as semiconductors, superconductivity, etc., physicists can not still advance a simple answer to the question, "What is an electron?". All that we have now is an impeccable mathematical tool in the form of a physical theory which is highly successful in every sphere of its applications.

A most fundamental concept in physics such as the "mass-energy equivalence", expressed in the form of the famous equation of Einstein, namely, $E=mc^2$, which .is the corner-stone principle in all nuclear interactions, binding energies of atoms and nucleons etc., makes an inconspicuous entry into physics through Special theory of Relativity (STR), as a corollary of a simple looking exercise to obtain the transformation equations between frames of references in relative motion. More strangely, the highly successful QM can not justify this equivalence principle on its own, even though it is the theory concerned about the energy exchanges and interactions of fundamental particles! We do not yet understand how an electron "knows" on its own that when some one attempts to accelerate it with very high electric fields it can not travel faster than the magnitude given by 'c', the velocity of light in vacuum!

The present paper attempts to ask such questions and answer them also by building a new unified foundation for QM and STR by postulating an internal structure to quantum particles such as the electrons. It gives a new role to the constant 'c' in physics by bringing this constant into the structure of these particles.

It is shown by this theory that the entire STR is restored as such without any revision and further it helps to understand physically why the mass of fundamental particles increases with velocity, why time dilation occurs, etc.

In QM this theory explains the Duality as arising due to the internal motion postulated which results in a helical trajectory of the fundamental particles. It also shows that the "complex" representation of the wave-function of QM indeed corresponds to this representation of a particle traveling along a helix in three dimensions. Energy quatization, the Uncertainty principle, etc., can all be understood on the basis of this helical model.

Recent discussions on Scroedinger's "zitterbewegung(zbw)" phenomenon in the literature seem to confirm this model. It was argued there that "zbw" is a real phenomenon and it corresponds to a particle going along a cylindrical helix in real space with a radius equal to Compton Wavelength giving a striking corroboration to the present proposal.

Of course such new models require strong experimental confirmation to gain acceptance which might take some time in the future. However, in the true spirit of science, such new and revolutionary concepts, if proved to be internally consistent, must merit wide publicity and discussion to strengthen the confidence in existing theories.

1. INTRODUCTION

The turn of the century witnessed the birth of two great theories, namely, Einstein's Special Theory of Relativity (STR) and Quantum Mechanics (QM). STR[1] attempted to make dynamics & electrodynamics compatible to each other. STR asserted that light travels with a constant velocity independent of the motion of source or observer. STR also revolutionized our concepts of absolute motion and absolute rest. STR proposed new laws of transformations between frames of reference in uniform relative motion. STR came out with many spectacular results which have been verified experimentally time and again.

QM[2] on its part, asserted that energy, momentum, angular momentum, etc., of fundamental particles such as electrons, when subjected to a constraint, can have only discrete values. QM gave a mathematical basis which is remarkably successful but devoid of intuitive physical models. In spite of its impressive successes in explaining many observed phenomena, QM is still ridden with many problems especially with its interpretation. Many, including its founding fathers have expressed doubts about its ability to represents reality[3-7].

2. RELATIVITY:

2.1 Mass-Energy Equivalence:

STR started with a modest objective of obtaining transformation equations between inertial frames and came out with many spectacular results. The results such as *time dilation*, *length contraction* and *mass increase with velocity*, say what happens when an observer in one inertial frame observes events in another frame which is in relative motion. But it is strange and interesting that the famous result $E = mc^2$. .(1), where E is the energy of a particle of mass m, and c the velocity of light in free space, also came out of this exercise. This "mass-energy equivalence" relation certainly goes beyond reference frames! Its validity is nor restricted to systems where the particles travel with velocities close to 'c'. It is a concept of physics which is more profound and fundamental than the transformation equations themselves! This basic equation is responsible for the understanding of nuclear energy conversions, binding energies of nuclei, etc. It was obtained for the first time as the corollary of the results of STR. Instead of STR coming out with such a fundamental equation, it might perhaps be more appropriate if the transformation equations can be derived out of this equation! It is all the more strange that QM, which is the most successful fundamental theory about energy, mass and momentum exchanges among micro particles did not come out with this fundamental result independently! After all any fundamental theory must include this "equivalence" principle at the foundation level. or must be capable of deriving it independently. But QM did not recognize such a fundamental equivalence relation in spite of its impressive successes in every filed of its applications. These facts bring into focus the need to understand this equation in all its profundity and more importantly the role of the fundamental constant c in physics.

2.2 Role Of The Constant 'c' :

Einstein's second postulate says that the magnitude of the velocity of light is the same in all inertial frames. This means that its magnitude is not affected by the motion of the source or the observer. Even though counter-intuitive, this postulate is accepted by all physicists because all the results of STR could be experimentally established with great precision. However, if we accept that this constant cannot be affected by the motion of source or observer, then the converse that this constant also on its part, CAN NOT affect the motion of source or observer, becomes equally true. Yet, if one sees the results of STR one finds that this constant 'c' DOES play an important role in determining the magnitudes of the changes that are brought about by STR such as length contraction, mass increase with velocity, time dilation, etc. This apparent contradiction in STR gives us a feeling that this constant must have a different more important and "active" role to play in physics than what is envisaged in STR at present. Presently it sets only a "passive" upper-limit to velocities of material particles such as electrons. Experiments have shown that the particles such as electrons when accelerated continuously with high electric fields do show a very definite tendency to saturate asymptotically at ‘c’. Though this is perfectly in accordance with STR, one still fails to understand, “How does any electron “know” on its own that it cannot travel faster than the magnitude ‘c’ ” ! We get a feeling that perhaps this “velocity limit” should be built into the structure of these fundamental particles such as electrons, if possible.

2.3 Einstein- Loretz Transformation Equations:

Let us briefly review the Einstein-Lorentz transformation equations which are based on the constancy of velocity of light for all inertial frames. Let observers in two frames S and S’, moving with relative velocity v between them, observe a light beam originating from the point **r** = **r’** = 0 at time t=t’=0. Since by the second postulate of STR, both observers will observe the wave front of light to move with the same velocity ‘c’, we can write

$x^2 + y^2 + z^2 - c^2t^2 = x'^2 + y'^2 + z'^2 - c^2 t'^2$ . . . . . (2) corresponding to the propagation of these light signals. This equation is used in STR as the necessary condition for the linear transformation equations between the two frames to satisfy. However, equation (2) is valid only for light signals which are unique as given by the second postulate.

Hence the transformation equations obtained by imposing this condition must be valid ONLY for light signals. But experimentally we find these equations are valid even for particles such as electrons. Therefore it seems that the condition expressed by eqn.(2) must have more wider and universal validity including material particles. Thus the constant ‘c’ must enter somehow the structure of these particles. This is what is being attempted here.

2.4 Relativity & Spin:

It is strange but true that the two fundamental theories, STR & QM have stood apart from the beginning and have to be brought together “by force”, that is QM must be made applicable even to particles which travel with velocities close to c. The two well known attempts to bring together STR & QM were by Sommerfeld and Dirac. Sommerfeld provided relativistic corrections to the orbital electrons in the Bohr’s theory of hydrogen atom and succeeded remarkably, though partially, in explaining the “*fine structure*” of spectral lines which we now know is due to the “spin” of the electrons. Dirac developed the Relativistic QM. Strangely he also obtained the features of spin automatically. These two coincidences cannot be brushed aside as “accidental”. There should be some link between STR, QM and spin.

2.5 Time Dilation:

Time dilation is a well established result of STR. One of the dramatic proofs of time dilation comes from the study of decay times of muons in cosmic ray showers[8]. On a careful observation it looks as though the muon was constantly aware of the time elapsed in its own "*proper*" rest frame and lives only according to this "*local standard time*" irrespective of its state of motion with respect to any other frame or observer ! This prompts us to believe that fundamental particles must have some kind of internal periodicity intrinsic to their structure which is independent of their external motion and this helps in keeping "time" in their "proper frames".

3. RESULTS OF QUANTUM MECHANICS:

3.1 Spin Of A Fundamental Particle:

Spin of a fundamental particle is well established in the mathematical language of QM but eludes a physical model. Several attempts were made to obtain physical model but they were not quite successful. In Magnetic Resonance experiments (which are so common these days and are used even in medical diagnosis) one measures very precisely, one of the striking characteristics of a spinning particle, namely the frequency of "*Larmor precession*" of the magnetic moment which in turn is a consequence of the spin of the electron. How can there be precession without something spinning actually?

3.2 Interpretation Of Quantum Mechanics:

QM is highly successful. But its interpretation, the so called *"Copenhagen Interpretation"* was opposed by many including some of its founding fathers. Yet many physicists are happy with QM and its impeccable mathematical apparatus and use it in their fields without worrying about its interpretation. There have been many attempts to arrive at alternative approaches. But QM stays as the most successful theory and may continue to be so for a long time to come. Perhaps no new theory can replace QM especially its mathematical formalism. But one cannot rule out a new interpretation on the basis of a new and hitherto unknown concept being proposed which perhaps can and should explain why the mathematical formulation of QM is working so very well! It is with this motivation and the fact that there is plenty of links among the three concepts - QM, STR and Spin, that a new model with a common foundation is proposed here[9].

4. THE NEW FOUNDATION

4.1 The Challenge:

"The challenge is to develop a theory of individual material systems, each obeying its own law of motion, whose mean behavior over an ensemble reproduces the statistical predictions of Quantum Mechanics.

The basis of a science is its ability to *predict*. To predict means to tell what will happen in an experiment that has never been done. How can we do that? By assuming that we know what is there, independent of the experiment.

We must extrapolate the experiments to a region where they have not been done. We must take our concepts and extend them to places where they have not yet been checked. If we do not do that, we have no prediction. So it was perfectly sensible for the classical physicists to go happily along and suppose that the position ---- which obviously means something for a baseball ---- mean something also for an electron. It was a sensible procedure".

This is what the great *Richard Feynman* said about the challenges faced by physicists in building consistent physical models.

4.2 The Postulates:

Postulate 1:
Every micro particle is endowed with two types of motion, an Internal Motion and an External Motion. The velocities, kinetic energies and momenta of these particles that we normally observe in our laboratories are only those corresponding to their external motion.

Postulate 2:
The internal motion is a circular motion in a plane with a radius characteristic of the mass of the particle. The radius is obtained by imposing the condition that the "action" corresponding to one revolution in its internal motion is equal to Planck's constant "h". The internal motion postulated is periodic and is the basis for measurement of time in the frame in which the particle is "at rest" with respect to its external motion.

Postulate 3:
When a particle has external motion, the internal (circular) motion is always in a plane normal to the external velocity.

Postulate 4:
The magnitude of the instantaneous velocity of the particle, which is the resultant of its internal and external velocities, is always equal to "c", the velocity of light in free space.

Postulate 5:
The angular momentum and the radius of the internal motion are unaffected by the external motion and are therefore the same for all observers.

Postulate 6:
Physical laws are the same in all inertial frames (postulate I of STR).

5. DISCUSSION:

5.1 Radius of Internal Motion:

When a particle (say, an electron) is at "rest", it has no external motion, but according to *postulate 1*, it has an internal motion. This is a circular motion with a radius a_o and its instantaneous linear velocity along the circular orbit is "c".

Further, if the particle is observed to be moving with an external velocity V_{EX} =v, then its internal velocity V_{IN} must be $V_{IN}=\sqrt{c^2-v^2}$, so that the resultant is still c satisfying *postulate 4*. From this we find that the changes in the internal velocities are small for variations in external velocities which are themselves small, but when the external velocities are close to c, there is significant variations in its internal velocity.

The action $\left|\int p.ds\right|$ for one revolution along the orbit is $m_o .c.2\pi.a_o$ where m_o is the mass and a_o the radius of the internal motion. From *postulate 2*, $m_o.c.2\pi.a_o= h$ or $a_o = \hbar /m_o c$ where $\hbar =h/2\pi$. This value of a_o corresponds to the Compton Wavelength.

5.2 Helical Trajectory:

Consider a particle (say, electron) moving along the Z-axis with an external velocity v. Its internal motion will be in XY-plane and the resultant trajectory would be a HELIX. A helix is a three dimensional wave with its projection on any two mutually perpendicular planes, having the axis of the helix as their line of intersection, would be Sine and Cosine waves. The pitch of the helix, which is the distance covered by the particle along its axis during one revolution around the axis.

6. RESULTS OF RELATIVITY

6.1 Einstein-Lorentz Condition

In the present model let a particle moving with an external velocity u, go from a point P(x,y,z) to a neighboring point Q(x+dx,y+dy,z+dz) during an infinitesimal time interval dt, as observed by an observer in S. Since the resultant velocity is always c, the infinitesimal displacement dr of the particle, according to the observer in S will be

$|dr|^2 = dx^2 + dy^2 + dz^2 = c^2\ dt^2$ or $c^2\ dt^2 - dr^2 = 0$ . . . . .(3)

Assume the same particle is observed by another person in frame S', which is moving with a uniform relative velocity v with respect to S. Now even though the resultant velocity of the particle would still be c, its internal & external components would be different. He would therefore observe the same motion between two points P(x',y',z'') and Q(x'+dx',y'+dy',z'+dz'') during a time interval dt'. The time scales are different in the frames as internal velocities are different. Therefore, displacement dr', according to frame S' will be

$|dr'|^2 = dx'^2 + dy'^2 + dz'^2 = c^2\ dt'^2$ or $c^2\ dt'^2 - dr'^2 = 0$ . . . (4)

Combining these two we get

$c^2\ dt^2 - dr^2 = 0 = c^2\ dt'^2 - dr'^2$ . . .(5). This should serve as the necessary condition for the transformation to satisfy. A closer look shows this is precisely the Einstein Lorentz condition. But the point is that this is not restricted now to light beams alone. Therefore if we derive the transformation equations using this condition we will get exactly the same set of equations that we get in STR. Hence this theory retains all the results of STR without any modification.

But let us see whether the model can interpret some of the results of relativity also conceptually.

The internal motion is to be taken as an intrinsic clock mechanism of the particle. For an observer at rest with respect to a particle in a frame S, the internal velocity of the particle would be c. But for an observer in S' moving with a relative velocity v with respect to S, it would be $\sqrt{c^2 - v^2}$ which is less than that in S.

In a given interval of time if the particle, according to the observer in frame S, makes *n* revolutions along its internal motion then according to the one in frame S' it would make only less number of revolutions since the internal velocity is small in S'.

Hence the period of revolution of the particle due to its internal motion as measured in S'(=T' s) would be greater than that observed in S (=T s).

Or $2\pi\ a_o = cT = \sqrt{c^2 - v^2}\ T'$

Or $T' = T / \sqrt{1-(v^2/c^2)}$ . . . . (6)

This explains time dilation in a simple manner.

6.2 Increase Of Mass With Velocity:

From postulates 2 & 5 we can arrive at the transformation equation for the mass of the particle from frame S to S'.

If m_o is the mass of the particle in the rest frame S, then the angular momentum of its internal motion in this frame would be $m_o\ c\ a_o$. However for the observer in frame S' it would be

$m \sqrt{c^2 - v^2}\ a_o$. Therefore, from the principle of conservation of angular momentum $m_o\ c\ a_o = m \sqrt{c^2 - v^2}\ a_o$ .Hence we get

$m = m_o \ / \sqrt{1-(v^2/c^2)}$ . . . . . (7) This is the famous result of STR. This can also be conceptually understood.

The restriction that the resultant velocity should always be c implies that any variation in the external velocity of the particle must result in a corresponding change in the internal velocity. But since that would alter the angular momentum of internal motion, the system opposes any attempt to increase the external velocity. This appears as an increase in the inertial mass of the particle. Of course this effect is seen only at external velocities that are close to c.

Thus the relativistic mass increase with velocity can be understood as a consequence of conservation of angular momentum of internal motion.

6.3 Mass Energy Relation:

The change in Kinetic Energy of a particle is obtained by using the relation $dE_T = \frac{d(mv)}{dt}.ds$ and since v = c here and $\frac{ds}{dt}$ is also "c", $dE_T = dm.\ c^2$. The change in kinetic energy when a particle starting from rest (mass $=m_o$) moves with a uniform velocity v (mass = m) is given by integrating dE_T between the limits m_o and m. Then

$$E_T = \int_{m_o}^{m} dm.c^2 \quad \text{OR } E_T = (m - m_o)\ c^2 \ldots\ldots (8).$$

This is also a well-known result in STR.

From (8) $mc^2 = E_T + m_oc^2$ or the kinetic energy plus the rest energy is equal to the quantity on the left hand side of the equation. But the sum of rest energy and kinetic energy is the total energy of the particle E. Hence total energy of the particle moving with velocity v is

$$E = m\ c^2 \ \ldots\ldots. (6)$$

7. RESULTS OF QUANTUM MECHANICS:

7.1 Wave Particle Duality:

In this model any particle moving along a "straight line" in the laboratory is in reality moving along a helical trajectory. Helix being a three dimensional wave can be associated with a wavelength equal to the "pitch" of the helix. A moving particle is thus automatically endowed with a wave aspect.

This shows that the "particles" such as electrons, etc., are really particles and have a wave aspect associated with them which are responsible for their diffraction etc.

If the external momentum of the particle is p_z along the Z axis(say), and λ is the pitch (wavelength) of the helix corresponding to distance traveled along the axis for one revolution along the internal motion, then from postulate 2, the action corresponding to this external motion is $p_z\lambda = h$. Therefore we can obtain an expression for the pitch (wavelength) λ as $\lambda=(h/p_z)$ which is the de Broglie's expression. From this we can obtain the standard expression for external momentum as $p_z = h/\lambda$ or $p_z = (h/2\pi).(2\pi/\lambda)$, which is identical to $p_z = \hbar.k_z$ where k_z is the "wave vector" along the Z axis. This can be generalized for the three-dimensional case as $\mathbf{p} = \hbar.\mathbf{k}$ . . . . (9)

7.2 Uncertainty Principle:

In this model, a simple one dimensional description of the motion of a fundamental particle is completely lost. Because of its helical trajectory the instantaneous position of the particle would be on an imaginary cylinder. For a particle moving along a "straight line" this leads to an uncertainty in its location (in XY plane) equal to the radius of the cylinder (Compton wavelength).

The minimum error in its location Δx or Δy is $\pm a_o$. i.e. Δx or $\Delta y \geq a_o$ The value of momentum is $m_o c$ and if we equate the uncertainty to this itself, Δp_x or $\Delta p_y = m_o c$. Hence $\Delta x.\Delta p_x$ or $\Delta y.\Delta p_y \geq a_o m_o c$ or $\Delta x.\Delta p_x$ or $\Delta y.\Delta p_y \geq \hbar$ . . . (7) which is the Uncertainty Relation.

7.3 Energy Quantization:

Can this model explain the existence of "quatization" of energy values? Let us pose the question differently, given that the particle passes through two points A and B in space with a finite separation between them, what are the paths the particle can trace and do they differ in energy values?

It is a well-known result in Variational Calculus that the shortest line between two points on a cylinder is a helix[10]. That is helix is a "geodesic" on a cylinder.

It is shown that between two fixed points on a cylinder there could be any number of such helixes depending on the number of times the path completely encircles the cylinder. The pitches of these helixes are related among themselves as below:

$$p_1 : p_2 : p_3 ..... : p_n : .... = \frac{1}{\theta} : \frac{1}{\theta + 2\pi} : \frac{1}{\theta + 4\pi} : .... : \frac{1}{\theta + 2(n-1)\pi} : ... (11)$$

where θ is the angle between the planes containing A &B parallel to the axis & having the axis of the helix as the line of intersection.

Since the observed direction of motion is along external velocity, we can choose the axis of helix parallel to AB (θ = 0) then

$$p_1 : p_2 : p_3 ..... : p_n : .... = 1 : \frac{1}{2} : \frac{1}{3} : .... : \frac{1}{n} : ... \qquad (12)$$

If v_1 is the external velocity in the "fundamental mode" then the period of internal motion is obtained from

$$\frac{2\pi a_o}{\sqrt{c^2 - v^2}} = \frac{p_1}{v_1} \quad \text{and for other modes} \quad \frac{2\pi a_o}{\sqrt{c^2 - v_n^2}} = \frac{p_n}{v_n}$$

From (12) $p_n = p_1 / n$ substituting & simplifying we get

$E_n = E_1 . \sqrt{1 - \frac{(n^2 - 1)}{n^2} . \frac{v_1^2}{c^2}}$ implying that the particle may have only one of a discrete set of energy values. In the limit $v \to c$, energy becomes $E_n = \frac{E_1}{n}$ . . . . . .(13)

The relationship between successive energy values becomes simple if we restrict the external velocity to small values compared to 'c'. Then the kinetic energy will be $E_n = \frac{1}{2} m_o v_n^2$ and substituting for v_n

$$E_n = \frac{1}{2} . m_o \frac{v_1^2}{n^2 \sqrt{1 - \frac{(n^2 - 1)}{n^2} . \frac{v_1^2}{c^2}}} \quad \text{and in the limit } \frac{v_1}{c} \to 0 \text{ we get } E_n = \frac{E_1}{n^2} \quad . . . . (14)$$

Thus the energy quantization comes as a natural consequence of the internal motion postulated.

7.4 Representation Of Helix:

Consider a particle "at rest", having only internal motion. It is moving along a circle in XY-plane with an angular velocity, say, ω about an axis passing through the centre along Z-axis.

The instantaneous position of the particle, with respect to the origin coinciding with the centre of the circle, is given by the tip of the rotating radius vector, which can be represented by

$x = a_o \text{Cos}\theta$ and $y = a_o \text{Sin}\theta$ and $z = 0$ where $\theta = \omega t$. The choice of x and y axes are arbitrary due to cylindrical symmetry.

We now make use of the symbol $\mathbf{j} = \sqrt{-1}$ which we interpret as an operator that rotates a vector by 90^0 in a counterclockwise direction without changing its magnitude. Therefore, $\mathbf{j}.\boldsymbol{\varepsilon}_\mathbf{x} = \boldsymbol{\varepsilon}_\mathbf{y}$ where $\boldsymbol{\varepsilon}_\mathbf{x}$, $\boldsymbol{\varepsilon}_\mathbf{y}$ are the unit vectors along x and y directions respectively.

Therefore, the position vector **r** becomes,

$$\mathbf{r}(t) = a_o \, \text{Cos}\omega t \, . \, \boldsymbol{\varepsilon}_x + a_o \, \text{Sin}\, \omega t \, . \, \boldsymbol{\varepsilon}_y$$

$$= a_o \boldsymbol{\varepsilon}_x (\text{Cos}\, \omega t. + \mathbf{j}\, \text{Sin}\, \omega t)$$

$$\mathbf{r}(t) = a_o \boldsymbol{\varepsilon}_x . e^{j\omega t} \quad \ldots .(10)$$ and if the rotation is in opposite sense

$$\mathbf{r}(t) = a_o \boldsymbol{\varepsilon}_x . e^{-j\omega t} \quad \ldots . (11)$$

Either of these two equations, (10) or (11) represents a particle at rest or "stationary" having no external velocity.

If we plot **r**(t) with respect to t we will get a helix along the time axis. This equation therefore tells us the position of the particle as a function of time.

But if we consider a particle traveling with an external velocity v along z-axis, then, since $z/\lambda = t/T = \theta / 2\pi$, where p is the pitch, we can write $\theta = 2\pi.z / \lambda = k.z$ and hence $\mathbf{r}(t) = a_o \boldsymbol{\varepsilon}_x . e^{jkz}$ where k can be interpreted as the wave vector.

The particle will trace even now a helix along the time axis. It will trace a helix along the z-axis also. It would be desirable to obtain its instantaneous position with respect to both z and t, i.e., **r**(z,t). After a time t, it would have traveled a distance v.t along z-axis. Hence the position of the particle at any z and at time t would be the same as at an earlier time [t- (z/v)] with respect to the xy-plane [11].
Therefore we can write $\mathbf{r}(z,t) = a_o . \boldsymbol{\varepsilon}_x . e^{j\omega[t-(z/v)]}$ or since $\omega/v = k$ we can write

$$\mathbf{r}(z,t) = a_o . \boldsymbol{\varepsilon}_x . e^{j(\omega t - kz)} \quad \ldots\ldots\ldots .(12)$$

This helps to establish a correspondence with quantum mechanics. In QM these "complex wave functions" can be obtained only mathematically and there is no physical justification for their successes. $e^{j\omega t}$ appears in QM in the representation of the wave function for the "stationary states", and this represents here in this model also a particle having only internal motion and hence "at rest" or stationary.

And in general the quantum mechanical wave function is represented as $\Psi(z,t) = A\, e^{j(\omega t - kz)}$ which in this model corresponds to the representation of any particle having both internal and external motions. This wave function is interpreted as representing the probability amplitude, the modulus square of which gives the probability of finding the particle in a given volume.

This is a very significant result. This model, therefore, has given a new phenomenological interpretation for the complex wave function of QM.

7.5 Expression For Energy:

The total kinetic energy of the particle consists of two parts: one is the KE of internal energy and the other due to external motion. For particles that travel with very small velocities compared to c, the energy due to internal motion is a very large component and almost a constant. Hence it remains practically a constant when interacting with similar particles having small velocities having comparable masses. Hence their KE due to external motion only have to be considered for looking at their trajectories etc. Thus their KE can be expressed as $E = p^2/2m$. . . . .. (13)

But if the particles have external velocities close to c then the contributions to total energy due to internal and external motions would be comparable. From *postulate 2*, the action for one revolution along internal motion is h the Planck's constant. If we now define total energy as the total action performed in unit time, then the particle makes $\omega/2\pi$ revolutions in one second. Hence the total action performed is

$$E = h.\ \omega/2\pi \text{ or } E = \hbar\omega \ . . . .(14).$$

This is a well-known expression in QM for energy.

7.6 Dirac's Electron:

When Dirac applied his relativistic equation to the free electron, he obtained a puzzling result: the *eigen* values of the velocity operator α was found to be ± 1 in natural units, i.e., $\pm c$! That is the instantaneous velocity of electron is $\pm c$. This result violates Einstein's relativity which says no particle can travel with velocity c.

Dirac argues ", ... the theoretical velocity in the above conclusion is the velocity at one instant of time while the observed velocities are always average velocities through appreciable time intervals".

In the present model this result of Dirac is not at all surprising. The Lorentz invariance condition itself is interpreted as an assertion of postulate 4 here and hence it led to a consistent result.

On further analysis of Dirac's equation it was found that the electron can have an oscillatory motion superposed on a steady motion. This oscillatory motion was called "zitterbewegung" (ZBW) by Schroedinger. This resulted in an intense activity among researchers to this day.

7.7 Zitterbewegung:

In recent years some physicists have come to believe that ZBW, which is a "localized circulatory motion", is a real physical phenomenon and that it provides a physical interpretation of the complex wave factor in Dirac's wave function[12-16].

It has also been shown using "space-time algebra" that ZBW can correspond in the classical limit to a motion of the electron along a cylindrical helix, whose diameter equals the Compton wavelength.

It has also been shown that electron's spin and magnetic moment can also be understood on the basis of this ZBW motion.

8. CONCLUSION

Thus by postulating an internal motion and an instantaneous velocity equal to c for any fundamental particle, it is seen that one can obtain a fairly consistent picture of the world of micro particles.

This model does not indulge in any mathematical abstractions. It has provided a new and conceptually simple and unified basis for the two great theories, namely STR and QM.

It has given a new interpretation to the "Complex Wave functions" of QM. It says the fundamental particles travel along a helical trajectory. It explains that fundamental particles can have only discrete set of paths to travel between two given points, which are energetically different, thereby justifying the idea of quantization in QM.

Looking at the state of physics today, one really gets overwhelmed by the developments after the birth of QM and Relativity. A whole new generation of physicists have come to believe very strongly about the statistical nature of micro physics. It would be unthinkable for them that a new model consistent with the view of great physicists like Einstein can be proposed and accepted at this stage. However, we must keep in mind that a simple "physical" theory will do more good towards unraveling the secrets of nature than a purely "mathematical" theory which "somehow" works! The present day physics can not explain what is the quantity ω that we find in the equation $E = \hbar\omega$, what does the experimentally measured λ (de Broglie wave length) of an electron represent in reality, why the wave function necessarily have to be "complex" , etc., etc.

Though what this model has shown is significant, what it should explain still is enormous. For example, one of the greatest mysteries of physics is the results of Young's double slit experiment conducted with low intensity electrons and photons. However even here this model shows some promise since here every individual particle does have an undulatory aspect associated with their propagation in free space along a helical trajectory. The interference pattern obtained is shown to be due to individual particles crossing either of the slits almost one by one! Hence it might be possible to simulate with modern computers an interaction of a group of particles traveling along helixes with a double slit of finite dimensions and obtain the distribution of these particles on the other side at the screen.

It is believed here that many more like-minded physicists would join in this great search for a "physical" theory which might improve the understanding of the mysteries of nature such as "super conductivity", "quantum mechanical tunneling", etc.

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