FTL Quantum Models of the Photon and the Electron

Richard F. Gauthier

Engineering and Physics Department, Santa Rosa Junior College, Santa Rosa, CA 95401 USA
707-332-0751, richgauthier@gmail.com

Abstract. A photon is modeled by an uncharged superluminal quantum moving at 1.414*c* along an open 45-degree helical trajectory with radius $R = \lambda / 2\pi$ (where λ is the helical pitch or wavelength). A mostly superluminal spatial model of an electron is composed of a charged pointlike quantum circulating at an extremely high frequency (2.5×10^{20} hz) in a closed, double-looped helical trajectory whose helical pitch is one Compton wavelength h/mc. The quantum has energy and momentum but not rest mass, so its speed is not limited by *c*. The quantum's speed is superluminal 57% of the time and subluminal 43% of the time, passing through *c* twice in each trajectory cycle. The quantum's maximum speed in the electron's rest frame is 2.515*c* and its minimum speed is .707*c* . The electron model's helical trajectory parameters are selected to produce the electron's spin $\hbar/2$ and approximate (without small QED corrections) magnetic moment $e\hbar/2m$ (the Bohr magneton μ_B) as well as its Dirac equation-related "jittery motion" angular frequency $2mc^2/\hbar$, amplitude $\hbar/2mc$ and internal speed *c*. The two possible helicities of the electron model correspond to the electron and the positron. With these models, an electron is like a closed circulating photon. The electron's inertia is proposed to be related to the electron model's circulating internal Compton momentum *mc*. The internal superluminality of the photon model, the internal superluminality/subluminality of the electron model, and the proposed approach to the electron's inertia as "momentum at rest" within the electron, could be relevant to possible mechanisms of superluminal communication and transportation.

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INTRODUCTION

Dirac's (1928a; 1928b) theory of the relativistic electron did not include a model of the electron itself, and assumed the electron was a point-like particle. Schrödinger (1930) analyzed the results of the Dirac equation for a free electron, and described a high-frequency *zitterbewegung* or jittery motion which appeared to be due to the interference between positive and negative energy terms in the solution. Barut and Bracken (1981) analyzed Schrödinger's *Zitterbewegung* results and proposed a spatial description of the electron where the *zitterbewegung* would produce the electron's spin as the orbital angular momentum of the electron's internal system, while the electron's rest mass would be the electron's internal energy in its rest frame. Barut and Thacker (1985) generalized Barut and Bracken's (1981) analysis of the internal geometry of the Dirac electron to a proper-time relativistic formalism. Hestenes (1973; 1983; 1990; 1993) reformulated the Dirac equation through a mathematical approach (Clifford algebra) that brings out a geometric trajectory approach to understanding *zitterbewegung* and to modeling the electron, such as identifying the phase of the Dirac spinor with the spatial angular momentum of the electron. A trajectory approach to the Dirac theory has also been utilized by Bohm and Hiley (1993), who describe the electron's spin angular momentum and its magnetic moment as due to the circulatory motion of a point-like electron. However, none of the above work in modeling the electron's jittery motion has a superluminal aspect.

The photon has previously been modeled geometrically with several approaches, with results quantitatively similar to those in the present superluminal quantum model of the photon. Ashworth (1998) used a classical model of the photon to obtain a radius $\lambda / 2\pi$ for the photon and a superluminal internal speed of 1.414*c*, the same quantitative results for the photon as in the present paper. Kobe (1999) obtained the same quantitative result for the photon

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radius as in the present paper, based on a helical approach and quantum mechanical considerations. Sivasubramanian *et al*. (2004), using a model of the photon that is helical and explicitly internally superluminal, independently arrived at the same radius $\lambda / 2\pi$ for a photon as in the present paper.

The objectives of the present paper are to 1) present a simply derived superluminal helical quantum model for the photon 2) present a related partly superluminal helical quantum model of the electron having experimental and theoretical features of the Dirac equation's electron, 3) relate the electron and photon models to the Heisenberg uncertainty relations, 4) propose a new approach to understanding the electron's inertia, 5) contrast the electron model with the stochastic electrodynamics approach to inertia and the electron's *zitterbewegung*, 6) suggest implications of the models for propulsion science, and 7) suggest approaches for testing the proposed models.

A UNIFIED SUPERLUMINAL QUANTUM APPROACH TO MODELING THE ELECTRON AND THE PHOTON

The present approach is a unified approach to modeling both the electron and the photon with superluminal helical trajectories. The electron model has several features of the Dirac electron's *zitterbewegung*. Point-like entities are postulated called quanta, but which are distinct from electrons and photons themselves, and which compose an electron or a photon. These quanta (which may be superluminal) have an energy *E*, with its associated frequency *f* and angular frequency $\omega = 2\pi f$, an instantaneous momentum $\vec{P}$ with its associated wavelength λ and wave number $k = 2\pi / \lambda$, and an electric charge (in the case of the electron). One quantum forms a photon or an electron. An electron's quantum oscillates between subluminality and superluminality, while a photon's quantum is always superluminal. These quanta move in helical trajectories, which may be open (for a photon) or closed (for an electron). Movement of one of these quanta along its trajectory produces an electron or a photon. The type of helical trajectory and the associated charge or lack of charge determines which particle is produced. More details about the models presented below are provided in Gauthier (2006).

THE SUPERLUMINAL QUANTUM MODEL OF THE PHOTON

A photon is modeled as a quantum traveling along an open helical trajectory of radius *R* and pitch (wavelength) λ. The trajectory makes an angle θ with the forward direction. In this helical trajectory, R, λ and θ are related geometrically by $\tan\theta = 2\pi R / \lambda$. By incorporating into the model the photon's experimentally known linear momentum $p = h / \lambda$ and the photon's experimentally known angular momentum (spin) $s = \hbar$, a second relationship is found: $\tan\theta = \lambda / 2\pi R$. Combining these two relationships containing $\tan\theta$ gives $\lambda = 2\pi R$. This result, combined with the photon's experimentally known energy relationship $E = h\nu$ where ν is the photon quantum's frequency, leads to the photon model, shown in Figure 1.

The photon model has the following properties:

1) The forward angle θ of the photon quantum's helical trajectory is 45°.
2) The radius of the photon's quantum's helical trajectory is $R = \lambda / 2\pi$
3) The speed of the photon's quantum is $c\sqrt{2} = 1.414..c$ along its helical trajectory.

Using these results, for a right-handed photon traveling in the +z direction, the equations for the trajectory of the superluminal quantum (neglecting a possible phase factor) are:

$$x(t) = \frac{\lambda}{2\pi}\cos(\omega t) \ ,$$
$$y(t) = \frac{\lambda}{2\pi}\sin(\omega t) \ , \tag{1}$$
$$z(t) = ct \ ,$$

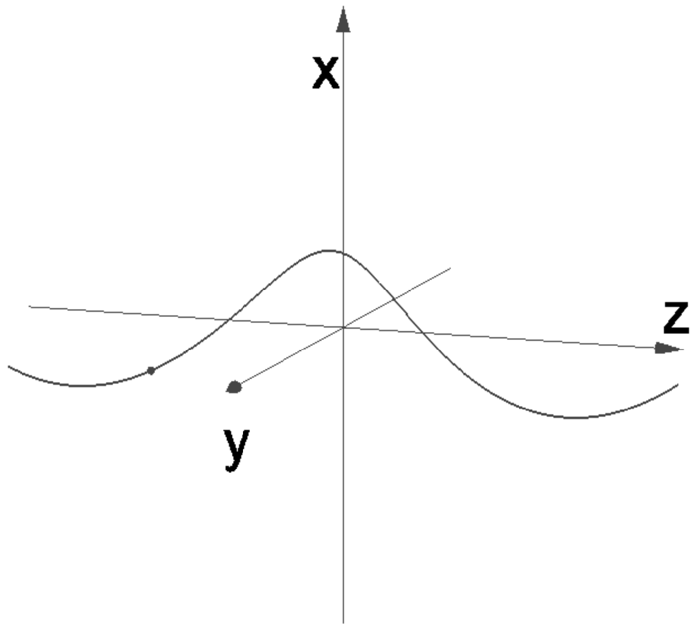


FIGURE 1. The Helical Trajectory of the Photon Model's Superluminal Quantum.

where $\omega = 2\pi f = 2\pi c / \lambda$ is the angular frequency of the photon, f is the photon's frequency in cycles per second and λ is the photon's wavelength. In the superluminal photon model, λ is the distance along the helical axis corresponding to one rotation of the superluminal quantum along its helical trajectory.

Similarly, for this right-handed photon, the equations for the components of the momentum of the superluminal quantum along its trajectory are:

$$\begin{aligned} p_x(t) &= -\frac{h}{\lambda}\sin(\omega t) \ , \\ p_y(t) &= \frac{h}{\lambda}\cos(\omega t) \ . \\ p_z(t) &= \frac{h}{\lambda} \ . \end{aligned} \tag{2}$$

The x and y components of momentum are 90 degrees out of phase with the x and y position values.

THE SUPERLUMINAL/SUMLUMINALQUANTUM MODEL OF THE ELECTRON

If the open helical trajectory of the photon model is converted into a closed, double-looped helical trajectory, the quantum gets an electric charge $-e$, and several helical parameters corresponding to an electron's experimental and theoretical properties are set, we get the superluminal/subluminal quantum model of the electron. Besides having the electron's experimental spin value and the magnetic moment of the Dirac electron, the superluminal/subluminal quantum model of the electron, described below, quantitatively embodies the electron's *zitterbewegung*.

Zitterbewegung refers to the Dirac equation's predicted rapid oscillatory motion of a free electron that adds to its center-of-mass motion. No size or spatial structure of the electron has so far been observed experimentally. High energy electron scattering experiments by Bender *et al*. (1984) have put an upper value on the electron's size at about 10^{-18} m. Yet Schrödinger's *zitterbewegung* results suggest that the electron's rapid oscillatory motion has a magnitude of $R_{zitt} = \frac{1}{2}\hbar / mc = 1.9\times10^{-13}$ m and an angular frequency of $\omega_{zitt} = 2mc^2/\hbar = 1.6\times10^{21}/\sec$, twice the angular frequency $\omega_0 = mc^2/\hbar$ of a photon whose energy is that contained within the rest mass of an electron. Furthermore, in the Dirac equation solution the electron's instantaneous speed is *c*, although experimentally observed electron speeds are always less than *c*. An acceptable model of the electron would presumably contain these *zitterbewegung* properties of the Dirac electron.

In the present superluminal quantum model of the electron, the electron is composed of a charged superluminal point-like quantum moving along a closed, double-looped helical trajectory in the electron model's rest frame, that is, the frame where the superluminal quantum's trajectory closes on itself. (In a moving inertial reference frame, the superluminal quantum's double-looped helical trajectory will not exactly close on itself.) The superluminal quantum's trajectory's closed helical axis' radius is set to be $R_0 = \frac{1}{2}\hbar / mc = 1.9\times10^{-13}\,\text{m}$ and the helical radius is set to be $R_{helix} = \sqrt{2}R_0$. The electron model structurally resembles a circulating photon model having angular frequency $\omega_0 = mc^2/\hbar$, wavelength $\lambda_C = h/mc$ (the Compton wavelength) and wave number $k = 2\pi/\lambda_C$. The electron's quantum moves in a closed double-looped helical trajectory having a circular axis of circumference $\lambda_C/2$. After following its helical trajectory around this circular axis once, the electron's superluminal quantum's trajectory is 180° out of phase with itself and doesn't close on itself. But after the superluminal quantum traverses its helical trajectory around the circular axis a second time, the superluminal quantum's trajectory is back in phase with itself and closes upon itself. The total longitudinal distance along its circular axis that the circulating superluminal quantum has traveled before its trajectory closes is λ_C.

In its rest frame, the electron's superluminal quantum carries energy $E = \hbar\omega_0 = mc^2$. Unlike the photon's superluminal quantum which is uncharged, the electron's superluminal quantum carries the electron's negative charge –*e*.

The above closed, double-looping helical spatial trajectory for the superluminal quantum in the electron model can be expressed in rectangular coordinates by:

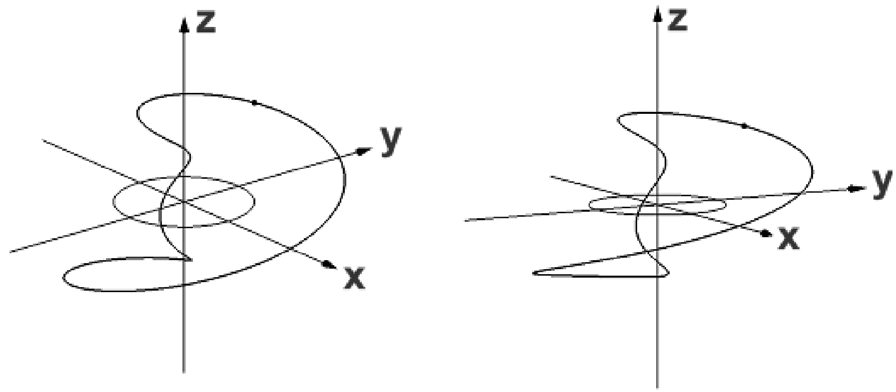
$$\begin{aligned} x(t) &= R_0(1+\sqrt{2}\cos(\omega_0 t))\cos(2\omega_0 t)\ , \\ y(t) &= R_0(1+\sqrt{2}\cos(\omega_0 t))\sin(2\omega_0 t)\ , \\ z(t) &= R_0\sqrt{2}\sin(\omega_0 t)\ , \end{aligned} \tag{3}$$

where $R_0 = \frac{1}{2}\hbar/mc$ and $\omega_0 = mc^2/\hbar$. These equations correspond to a left-handed photon-like object of wavelength λ_C, circulating counterclockwise (as seen above from the +z axis) in a closed double loop. Two images from different perspectives of the superluminal quantum model of an electron are shown in Figure 2.

The velocity components of the superluminal/subluminal quantum are obtained by differentiating the position coordinates of the superluminal quantum in equation (3) with respect to time, giving:

$$\begin{aligned} v_x(t) &= -c[(1+\sqrt{2}\cos\omega_0 t)\sin 2\omega_0 t + \frac{\sqrt{2}}{2}\cos 2\omega_0 t \sin\omega_0 t]\ , \\ v_y(t) &= c[(1+\sqrt{2}\cos\omega_0 t)\cos 2\omega_0 t - \frac{\sqrt{2}}{2}\sin 2\omega_0 t \sin\omega_0 t]\ , \\ v_z(t) &= c\frac{\sqrt{2}}{2}\cos\omega_0 t\ . \end{aligned} \tag{4}$$

From equation (4) it is found that the maximum speed of the electron's quantum is 2.515*c*, while its minimum speed is .707*c*. A graph of the speed of the electron's quantum versus the angle of rotation in the y-z plane as the electron's



(a) First Perspective. **(b)** Second Perspective.

FIGURE 2. Two Perspectives of the Closed Double-looped Helical Trajectory of the Electron Model's Superluminal/Subluminal Quantum. (The Circle in the x-y Plane is the Axis of the Closed Helix.)

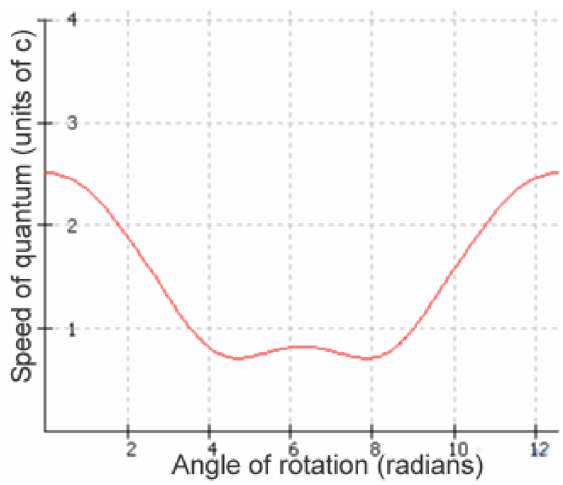


FIGURE 3. Speed of the Electron Model's Quantum along its Double-looped Helical Trajectory.

quantum circulates in its closed double-looped helical trajectory is shown in Figure 3. The quantum completes each trajectory cycle in 12.56 or 4π radians.

The circulating quantum spends approximately 57% (more precisely 56.640475%) of its time (measured in the electron model's rest frame) traveling superluminally along its trajectory and 43% (more precisely 43.359525%) of its time traveling subluminally. The quantum twice passes through the speed value *c* while completing one closed helical trajectory. This passage of the quantum from superluminal speeds through *c* to subluminal speeds and back again to superluminal speeds is not a problem from a relativistic perspective. This is because it is the point-like electric charge -*e* that is moving at these speeds and not the average center of mass/energy of the electron model, which remains at rest in the electron model's rest frame.

SIMILARITIES BETWEEN THE DIRAC EQUATION'S FREE ELECTRON SOLUTION AND THE QUANTUM MODEL OF THE ELECTRON

The superluminal quantum model of the electron share a number of quantitative and qualitative properties with the Dirac equation's electron with *zitterbewegung*:

1) The *zitterbewegung* internal frequency of $\omega_{zitt} = 2mc^2/\hbar = 2\omega_0$.

2) The *zitterbewegung* radius $R_0 = \frac{1}{2}\hbar/mc = R_{zitt}$. Using the equations (3) the rms values of x, y and z, which are the values of Δx, Δy and Δz in the Heisenberg uncertainty relation, are all calculated to be $R_0 = \hbar/2mc$, where R_0 is the radius of the closed helical axis of the superluminal electron model. This is the also value of the amplitude of the electron's jittery motion found by Schrödinger (1930). These rms results are predictions of the electron model, and are only obtained when the radius of the superluminal quantum's helix is $R_0\sqrt{2}$ as used in equation (3). This value $R_0\sqrt{2}$ is the helical radius required to give the electron model's z-component of its magnetic moment a magnitude equal to the Dirac equation's magnitude of one Bohr magneton μ_B .

3) The *zitterbewegung* speed-of-light result for the electron.

4) The prediction of the electron's antiparticle, having opposite helicity to the electron model's helicity.

5) The calculated spin of the electron.

6) The calculated Dirac magnetic moment of the electron $M_z = -\mu_B$. In the electron model, $M_x = 0$ and $M_y = -.25\mu_B$, which differs from the Dirac result.

7) The electron's motion is the sum of its center-of-mass motion and its *zitterbewegung.*

8) The non-conservation of linear momentum in the *zitterbewegung* of a free electron, a result first pointed out for the Dirac electron by de Broglie (1934).

THE HEISENBERG UNCERTAINTY PRINCIPLE AND THE MODELS OF THE PHOTON AND THE ELECTRON

With the superluminal quantum model of the photon, the superluminal quantum would be what is actually detected when a single photon is detected in an experiment. Suppose a photon is traveling in the +z direction. Because of its varying position and momentum components as it moves along its trajectory, a range of values of its *x* and *y* components of position and momentum would be detected when various photons traveling in the +z direction are measured successively.

A remarkable aspect of the superluminal model of the photon is that the superluminal quantum's position and momentum components are found to be quantitatively closely related to the Heisenberg uncertainty relation. This relation says that there is a fundamental limitation on the accuracy of simultaneously measuring two related physical properties, such as the corresponding position and momentum components, of an elementary particle or other physical object. Greater accuracy in measuring one of the two properties entails a corresponding lesser accuracy in measuring the corresponding property. The Heisenberg uncertainty relationship for the *x* coordinate of a particle is stated precisely as $\Delta x\, \Delta p_x \geq h/4\pi$, where Δx is the standard error (the square root of the statistical variance) in measuring the position of the particle along the *x* direction , Δp_x is the standard error in measuring the particle's momentum along the same *x* dimension, and *h* is Planck's constant. How does the Heisenberg uncertainty relation apply to detecting a photon in the superluminal photon model? Using the $x(t)$ equation for transverse position and $p_x(t)$ equation for the transverse momentum in the photon model in equation (2), the root-mean-square value or Δx for $x(t)$ is found to be:

$$\Delta x = \frac{1}{\sqrt{2}}\frac{\lambda}{2\pi} \ , \tag{5}$$

while the root-mean-square value Δp_x for $p_x(t)$ is found to be:

$$\Delta p_x = \frac{1}{\sqrt{2}}\frac{h}{\lambda} \ . \tag{6}$$

Multiplying these rms values Δx and Δp_x for the superluminal quantum model of the photon gives:

$$\Delta x \Delta p_x = (\frac{1}{\sqrt{2}}\frac{\lambda}{2\pi})(\frac{1}{\sqrt{2}}\frac{h}{\lambda}) = \frac{h}{4\pi} \ . \tag{7}$$

Comparing this result with the Heisenberg uncertainty relation:

$$\Delta x \Delta p_x \geq \frac{h}{4\pi} \ , \tag{8}$$

we see that the uncertainty product of the transverse or x components of position and momentum for the superluminal quantum in the photon model is exactly the minimum value allowed by the Heisenberg uncertainly relation. The same quantitative results are found for Δy and Δp_y, the rms values for the y components of position and momentum of the superluminal quantum in equations (1) and (2). For the photon model:

$$\Delta y \Delta p_y = \frac{h}{4\pi} \ . \tag{9}$$

Any real photon will have a finite value of uncertainty in the coordinates of both its position and its momentum. A photon, until it is detected, is described quantum mechanically by a mathematical superposition of position states or their corresponding momentum states, each corresponding to a particular wave function with a particular amplitude, frequency and phase. This total quantum wave function describing the photon is then related to the probability of detecting the photon in the regions where the total wave function is non-zero. The superluminal photon model seems to be consistent with the quantum mechanical interpretation of the photon and the Heisenberg uncertainty principle.

Similarly, the electron is modeled as a helical photon-like object moving in a circle at the *zitterbewegung* angular frequency $\omega_{zitt} = 2mc^2/\hbar$ with a forward velocity c and Compton momentum $p_C = h/\lambda_C = mc$ (where λ_C is the Compton wavelength h/mc of the photon-like object composing the electron). This circle (see Figure 2) is the circular axis (of radius $R_{zitt} = \frac{1}{2}\hbar/mc$) of the electron model's helix. The rms values for position in the electron model in the x, y and z directions all give $R_{rms} = \frac{1}{2}\hbar/mc$ as mentioned earlier. Combining this rms position result with the calculated rms value $mc/\sqrt{2}$ for the circulating momentum mc gives:

$$\Delta x \Delta p_x = (\frac{1}{2}\hbar/mc)(\frac{1}{\sqrt{2}} \cdot mc) = .707 \cdot \frac{1}{2}\hbar = .707\frac{h}{4\pi} \ , \tag{10}$$

$$\Delta y \Delta p_y = (\frac{1}{2}\hbar/mc)(\frac{1}{\sqrt{2}} \cdot mc) = .707 \cdot \frac{1}{2}\hbar = .707\frac{h}{4\pi} \ . \tag{11}$$

The relations in (10) and (11) for the electron model contain a value .707 times that in the Heisenberg uncertainty relation. These position/momentum relations for the electron model would not be experimentally detectable in principle, according to the Heisenberg uncertainty relation. Furthermore, since these relations are not detectable in principle, the electron model would not violate conservation of linear momentum, even though its internal momentum vector rotates at the *zitterbewegung* angular frequency $\omega_{zitt} = 1.6 \times 10^{21}/\sec$. Yet the electron model has the electron's spin value $s = R_{zitt}\, p = (\frac{1}{2}\hbar/mc)(mc) = \frac{1}{2}\hbar$, which is detectable. This rotating internal momentum $p = mc$ would give rise to the electron's rest mass m, and therefore the electron's inertia.

THE ELECTRON MODEL AND INERTIA

The electron model may provide a new approach to understanding the nature of inertia, a deeper understanding of which would be highly relevant to propulsion science. The electron is modeled as a double-looping circulating photon-like object having an internal Compton wavelength $\lambda_C = h/mc$ and therefore a Compton momentum $p_C = h/\lambda_C = mc$. This internal Compton momentum is rotating at the *zitterbewegung* angular frequency $\omega_{zitt} = 2mc^2/\hbar = 1.6\times10^{21}/\sec$. The well-known relativistic equation relating the total energy E of an electron to its linear momentum p and its rest mass m is $E^2/c^2 = p^2 + (mc)^2 = p_x^2 + p_y^2 + p_z^2 + (mc)^2$. In the electron model, an electron with a 'rest mass' m is never internally at rest. The electron model has a rotating linear momentum $p_C = mc$ which is mathematically on an equal footing with the electron's three linear momentum components p_x, p_y and p_z. (It is the rapidly rotating linear momentum in the electron model that gives the electron its spin $\frac{1}{2}\hbar$.) The total relativistic energy E of an electron is then given by $E^2/c^2 = p^2 + p_C{}^2 = p_x^2 + p_y^2 + p_z^2 + p_C{}^2$.

It may be that the rotation of an electron's internal Compton momentum $p_C = mc$ at the *zitterbewegung* frequency $\omega_{zitt} = 2mc^2/\hbar = 1.6\times10^{21}/\sec$ is what given an electron its inertia, that is, its resistance to being accelerated by either an applied external force or by gravity. The inertia of an electron (as measured by its mass m) is then related directly to its internally rotating Compton momentum $p_C = mc$ and only indirectly to the electron's "rest energy" $E = mc^2 = p_C c$ (when $p_x = p_y = p_z = 0$). Momentum is often described as 'inertia in motion'. With the electron model this can now be turned around: inertia is 'momentum at rest', where 'at rest' is only apparent. Momentum is more fundamental than mass, since in an isolated system the total linear momentum is conserved, but the total mass is not necessarily conserved.

COMPARISON OF THE ELECTRON MODEL WITH THE SED/ZPF APPROACH

The present superluminal/subluminal model of the electron, by a suitable choice of several parameters associated with the closed helical trajectory of its circulating quantum, is consistent with a number of experimental and theoretical properties of the electron. These include the Dirac electron's three principal *zitterbewegung* parameters described by Schrödinger (1930): the *zitterbewegung* angular frequency $\omega_{zitt} = 2mc^2/\hbar = 1.6\times10^{21}/\sec$, the *zitterbewegung* amplitude $R_{zitt} = \frac{1}{2}\hbar/mc = 1.9\times10^{-13}$ m and the speed-of-light motion of the electron. Since nothing is actually at rest in the present electron model, the electron's inertia would be determined by its internal momentum, which is rapidly rotating at the *zitterbewegung* angular frequency.

A different though perhaps related approach to the generation of the electron's inertia and its *zitterbewegung* is described in Haisch and Rueda (2000) and in articles referenced therein. In that approach, where stochastic electrodynamics (SED) is used to describe the zero-point field (ZPF), the inertia of objects may result in part from the scattering of background zero-point radiation by these objects when they accelerate. The *zitterbewegung's* high frequency oscillations would be produced by the electron's resonant interaction with the (ZPF) at or near the electron's Compton frequency. The ZPF, in resonating with a moving electron, would also generate the de Broglie wavelength $\lambda_{deBroglie} = h/p$ (where p is the electron's momentum) through the beat frequencies and wavelengths associated with relativistic Doppler shifting of the electron's internal standing wave frequency structure.

The SED/ZPF approach to *zitterbewegung* and inertia is built on experimental and theoretical research describing the existence and stochastic properties of the ZPF with its associated high energy density of the vacuum. While the SED/ZPF approach has had some success in predicting certain statistical relations described by quantum mechanics, it has not arrived at the non-relativistic Schrödinger equation nor the relativistic Dirac equation. Still, the approach suggests a close relationship between the electron's *zitterbewegung* and its inertia.

Although differing in their approaches, the present electron model and the SED approach to the electron and its *zitterbewegung* have points in common. They both assume that the electron is fundamentally associated with a field. In the case of SED, the electron would be a creation of the electromagnetic field. The electron's *zitterbewegung* would be maintained by the background ZPF. In the present electron model, an electron is a circulating photon-like object. Photons and electrons are described by quantum electrodynamics (QED). Also, both approaches rely on de Broglie's equation $hf = mc^2$, which associates the rest mass of an electron with a frequency of the electron at rest.

In the SED approach, this frequency provides the resonance frequency for the ZPF to make contact with and energize the electron. In the present electron model, this de Broglie frequency gives the double-looping structure its *zitterbewegung* angular frequency $\omega_{zitt} = 2mc^2 / \hbar = 1.6 \times 10^{21} / \sec$, which is twice the de Broglie angular frequency.

IMPLICATIONS OF THE MODELS FOR PROPULSION SCIENCE

The electron model (which is derived from the photon model) may have two possible implications for propulsion science. First, the electron model's internal quantum is sometimes internally subluminal and sometimes superluminal. Since the quantum carries electric charge but not mass, it can pass from subluminal to superluminal speeds without facing the speed-of-light barrier that a physical mass would face. If the electron's quantum could be kept superluminal for a period of time, it might be transported superluminally from one location to another, before returning to the normal subluminal/superluminal cycle of an electron. This would result in FTL travel of the electron.

Second, if the inertia of an electron is a measure of its high-frequency internally rotating Compton momentum, this suggests that changing the internally rotating momenta within an object may change the object's inertia and consequently its resistance to any propulsive forces. This proposal could lead to experimental tests and to practical benefits in the field of propulsion science, such as lower spaceship mass and correspondingly reduced fuel costs.

TESTING THE PHOTON AND ELECTRON MODELS

Since equation (7) shows that the variation in the transverse position and momentum components of the photon model is at the exact limit of the Heisenberg uncertainty relation, it appears that the photon model can be tested by measurements of a photon's position and momentum. Knowledge of the phase of the photon's quantum in equations (1) and (2) would permit a theoretical specification of the quantum's instantaneous position and momentum. Perhaps such phase relations could be tested experimentally using two-photon coincidence counts as proposed by Sivasubramanian (2004). Another approach to testing the proposed $\lambda / 2\pi$ radius of the photon model is by analyzing the cutoff frequencies for microwaves transmitted in waveguides of different sizes, as did Ashworth (1998). The prediction is that a waveguide will not transmit microwaves as well, as indicated by the waveguide cutoff frequency, if the diameter of the waveguide is less than the diameter of a microwave's photon. Although the cutoff frequencies of waveguides are related to wavelength λ for rectangular waveguides, the possible relation of cutoff frequencies to $\lambda / 2\pi$ is not so straightforward for other geometries and could be researched further, perhaps using waveguides with non-standard geometries.

There could be tests of the electron model's helical structure. An electron and a positron would differ in the direction of their internal helicities. If the electron were structured like a circulating left-handed photon, then a positron would be structured like a circulating right-handed photon, and vice versa. Electrons could therefore differentially absorb, scatter or otherwise interact with differentially polarized gamma photons, for example with differentially polarized gamma photons having energies corresponding to the rest mass of electrons.

It is proposed that the electron may generate its inertia by the rapid rotation of its internal Compton momentum $p_C = mc$ at the electron's *zitterbewegung* frequency. This rotating momentum is associated with the circulation of the electron model's point-like charge at the same high frequency. Subatomic effects can show themselves at the macroscopic level, for example as in magnetic materials. The rotation of a macroscopic physical object at a particular frequency could shift the rotational rate of the Compton momentum of electrons by a corresponding frequency, depending on the alignment of the electrons with the rotational direction of the macroscopic object. This leads to a testable prediction that the inertia of the rotating object could change with its angular velocity. The object could become more or less massive, with a correspondingly larger or smaller weight. A variety of claims about anti-gravity devices as well as above-unity energy devices are associated with rotating magnets and other rotating objects. It may be that the inertia hypothesis associated with the electron model could help provide an explanation for experimentally observed inertia-altering phenomena. The inertia explanation in the electron model can also lead to new proposals for experiments in inertia alteration, which could be then subjected to experimental tests. Positive results would of course lead to a better understanding of inertia, while negative experimental results would be informative as well.

CONCLUSION

The photon and the electron are modeled as helically circulating point-like quanta having both particle-like (E and $\vec{P}$) and wave-like (ω and λ) characteristics. The number of quantitative and qualitative similarities between the Dirac electron with *zitterbewegung* and the proposed superluminal/subluminal quantum model of the electron is remarkable, given the relatively simple mathematical form of the electron quantum's trajectory. This suggests that the superluminal/subluminal quantum concept for the electron and the superluminal quantum model for the photon may provide useful physical models for the electron and the photon and perhaps for other elementary particles as well. The superluminal/subluminal model of the electron and the superluminal model of the photon would be particularly interesting if they could be confirmed experimentally and then harnessed in a practical way for superluminal communication and/or transportation. A new approach to inertia as "momentum at rest" is presented.

NOMENCLATURE

m = mass of the electron (9.11×10^{-31}kg)
h = Planck's constant ($6.63\times10^{-34}\,\mathrm{kg\cdot m^2/s}$)
$\hbar$ = Planck's constant divided by 2π
c = the speed of light (3.00×10^{8} m/s)
μ_B = the Bohr magneton ($9.27\times10^{-24}\,\mathrm{A\cdot m^2}$)

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