Quantum-Vortex Electron Formed From Superluminal Double-Helix Photon in Electron-Positron Pair Production

Richard Gauthier
Department of Chemistry and Physics
Santa Rosa Junior College
Santa Rosa, CA, USA
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Abstract

A superluminal quantum-vortex model of the electron and the positron is produced from a superluminal double-helix model of the photon during electron-positron pair production. The two oppositely-charged (with $Q = \pm e\sqrt{2/\alpha} = 16.6e$) open-helix spin-½ half-photons compose the double-helix photon. These half-photons separate and curl up their separated superluminal single-helical trajectories to form an electrically-charged superluminal closed-helix spin-½ quantum-vortex electron model and a corresponding positron model. The helical radius and the Dirac equation's *zitterbewegung* angular frequency of the quantum vortex electron and positron models equal the helical radius and *zitterbewegung* angular frequency of the two spin-½ half-photons, each of energy $E = mc^2$, that composed the double-helix photon model of energy $E = 2mc^2$ from which the electron and positron models were produced. The photon and electron models are also compatible when a photon of energy $E > 2mc^2$ produces a relativistic electron-positron pair. Implications of the quantum vortex electron model for electron stability are discussed.

Key words: photon, electron, positron, quantum, vortex, superluminal, pair production, zitterbewegung, model, fine structure constant, helix, torus

Introduction

The production of electron-positron pairs from single photons was first observed in 1933 by Patrick Blackett (see https://en.wikipedia.org/wiki/Pair_production) soon after the discovery of the predicted antiparticle, the positron, by Carl D. Anderson (see https://en.wikipedia.org/wiki/Positron) in 1932. While physicists have carefully measured and theorized about electron-positron pair production from a photon, the process of transforming a photon into an electron-positron pair has remained unexplained. This article is not meant to review various 3D models of the photon and the electron. The present article suggests how one proposed 3D double-helical model of the photon (described in Gauthier[1]) can be transformed into a proposed 3D closed-helical model of the electron and the positron during electron-positron pair production. In the proposed transformation process, amplitude and frequency parameters of the double-helix photon model equal the corresponding amplitude and frequency parameters of the electron and positron models. This transformation process can be conceived of as continuous process.

A key feature of modeling this transformation process is that the incoming photon is proposed to be a double-helix composite structure of two mutually circulating oppositely-charged single-helix half-photons that separate during e-p production and curl up their trajectories to become a quantum vortex electron and positron pair. A second key feature is that both the double-helix photon model and the quantum vortex electron and positron models are proposed to be internally superluminal (by means of a proposed helically-circulating electrically-charged point-like superluminal energy quantum.) This internal superluminality is maintained before, during and after the transformation process, even though the double-helix photon model itself moves forward at light speed and the quantum vortex electron and positron models move forward at sub-light speeds.

The equations for the two half-photons forming the double-helix photon model

The position and momentum component equations for the superluminal energy quanta composing the two half-photons of a double-helix photon of wavelength λ, angular frequency ω and energy $E = \hbar\omega$ and having total spin $+1\hbar$ are given below:

Helix 1

$$
\begin{aligned}
x_1(t) &= \frac{\lambda}{2\pi}\cos(\omega t) & p_{x1}(t) &= -\frac{h}{2\lambda}\sin(\omega t) \\
y_1(t) &= \frac{\lambda}{2\pi}\sin(\omega t) & p_{y1}(t) &= \frac{h}{2\lambda}\cos(\omega t) \\
z_1(t) &= ct & p_{z1}(t) &= \frac{h}{2\lambda}
\end{aligned}
\qquad (1)
$$

Helix 2

$$
\begin{aligned}
x_2(t) &= -\frac{\lambda}{2\pi}\cos(\omega t) & p_{x2}(t) &= \frac{h}{2\lambda}\sin(\omega t) \\
y_2(t) &= -\frac{\lambda}{2\pi}\sin(\omega t) & p_{y2}(t) &= -\frac{h}{2\lambda}\cos(\omega t) \\
z_2(t) &= ct & p_{z2}(t) &= \frac{h}{2\lambda}
\end{aligned}
\qquad (2)
$$

Each electrically charged superluminal energy quantum composing a half-photon moves in a 45-degree helical trajectory of radius $\lambda / 2\pi$ with the speed $c\sqrt{2} = 1.414c$. The separation of the two charged quanta is therefore $D = \lambda / \pi$. The charges of the two energy quanta are $\pm e\sqrt{2/\alpha} = \pm 16.6e$, where $\alpha = 1/137.04$ is the fine structure constant of quantum electrodynamics (QED). The longitudinal p_z and transverse p_{trans} linear momentum components of the two half-photons are each $h/2\lambda$, giving the double-helix photon model the photon's experimental linear momentum of $p = h/\lambda$. The spin of each of the half-photons is $s = R \times p_{trans} = \lambda/2\pi \times h/2\lambda = \frac{1}{2}h/2\pi = \frac{1}{2}\hbar$. The total spin of the double-helix photon model is $S_{total} = 1\hbar$. See Figure 1.

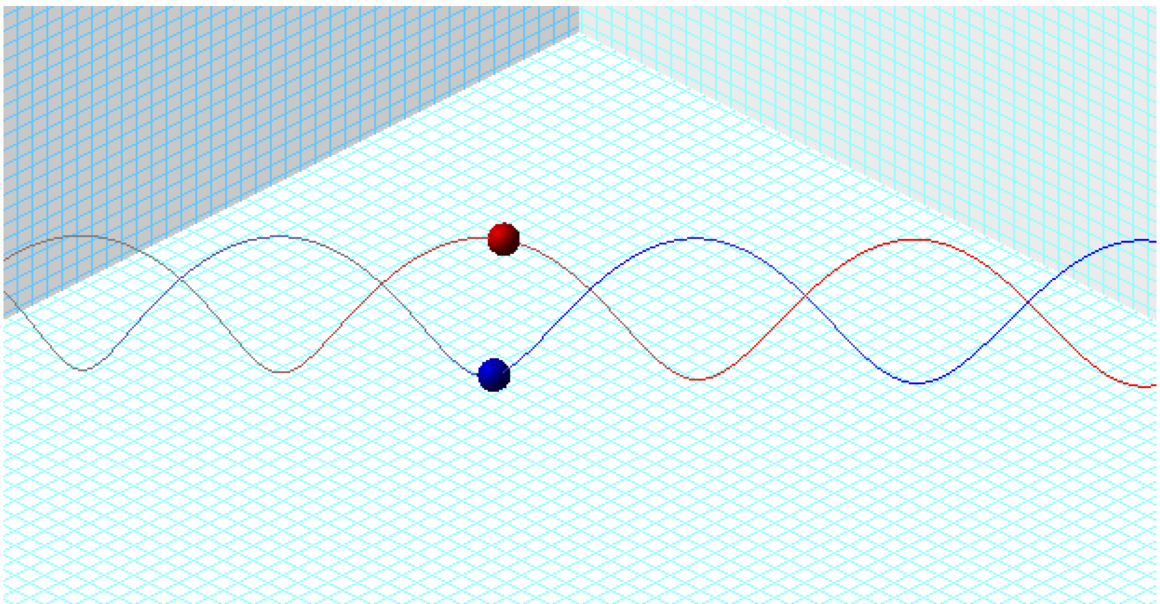

Figure 1. The superluminal double-helix model of the photon, showing the two superluminal energy quanta (which are actually point-like) moving on 45-degree helical trajectories at a speed $c\sqrt{2}$ or 1.414 *c*, separated by a distance $D = \lambda/\pi$ where λ is the wavelength of the photon. Each superluminal quantum composes a spin-½ half-photon. The double-helix photon model has calculated spin $S = 1\hbar$. Figure copyright ©2018 by Richard Gauthier.

The equations for the superluminal half-photon quantum vortex for an electron or a positron

Electron-positron pairs are produced when a sufficiently energetic photon, of at least the energy of an electron plus a positron, or $E = 2mc^2$, passes near an atomic nucleus and is converted to an electron and a positron. The atomic nucleus absorbs excess momentum from the photon to electron-pair conversion but doesn't otherwise participate in the conversion process. Parametric equations for the *x*, *y* and *z*-coordinates of a proposed circulating superluminal energy quantum forming a superluminal quantum-vortex model of the electron or positron are given (in Gauthier[2]) as:

$$
\begin{aligned}
x(t) &= \frac{\lambda_C}{4\pi}(1+\cos\omega_{zitt}t)(\cos\omega_{zitt}t) \\
y(t) &= \frac{\lambda_C}{4\pi}(1+\cos\omega_{zitt}t)(\sin\omega_{zitt}t) \qquad (3) \\
z(t) &= \frac{\lambda_C}{4\pi}(\sin\omega_{zitt}t)
\end{aligned}
$$

where $\lambda_C = h/mc = 2.43\times10^{-12}\,\mathrm{m}$ is the Compton wavelength. The proposal is that two spin-½ half-photons, each composed of a helically-circulating superluminal energy quantum, are separated during electron-positron pair production from a double-helical photon model. These two superluminal energy quanta curl up their respective trajectories to form closed-helix models of an electron and positron. This electron model is called the quantum vortex model of the electron. $R_o = \lambda_C/4\pi$ in the equations above is the helical radius of the quantum-vortex electron model. R_o is also the radius of a double-helix photon model of energy $E = 2mc^2 = 1.022MeV$, which is the sum of the rest energies of an electron and positron, each of $E_o = mc^2 = 0.511MeV$. The angular velocity $\omega_{zitt} = 2\pi\nu_{zitt} = 2mc^2/\hbar = 1.55\times10^{21}$ radians/sec is the electron's *zitterbewegung* angular frequency predicted by the relativistic Dirac equation.

The circulating superluminal energy quantum for the electron has a point-like electric charge of -1e, while for a positron the electric charge is +1e. The superluminal energy quantum in a resting quantum-vortex electron circulates with angular frequency ω_{zitt} in a closed helical trajectory whose circular helical axis has a circumference $C = \lambda_{Compton}/2$ and radius $R_o = \lambda_{Compton}/4\pi$. The superluminal energy quantum in the quantum-vortex model moves along the surface of a mathematical horn torus of helical radius $R = \lambda_C/4\pi$. From formula (3) above, the calculated maximum speed of the superluminal energy quantum in a resting quantum vortex electron model is $V_{\max} = c\sqrt{5} = 2.236c$. This is the speed of the superluminal energy quantum when it crosses the outer equator of the horn torus. The minimum speed of the superluminal energy quantum is calculated to be $V_{\min} = c$. This is the instantaneous speed of the superluminal energy quantum when it passes through the exact center of the horn torus. See Figure 2 below. The double-helix photon travels forward with a velocity c, while having an internal superluminal speed $c\sqrt{2}$, while the resting quantum vortex electron model has a maximum superluminal speed $V_{\max} = c\sqrt{5}$ and a minimum speed $V_{\min} = c$, due the superluminal energy quantum moving in a closed helical trajectory in the resting quantum-vortex electron.

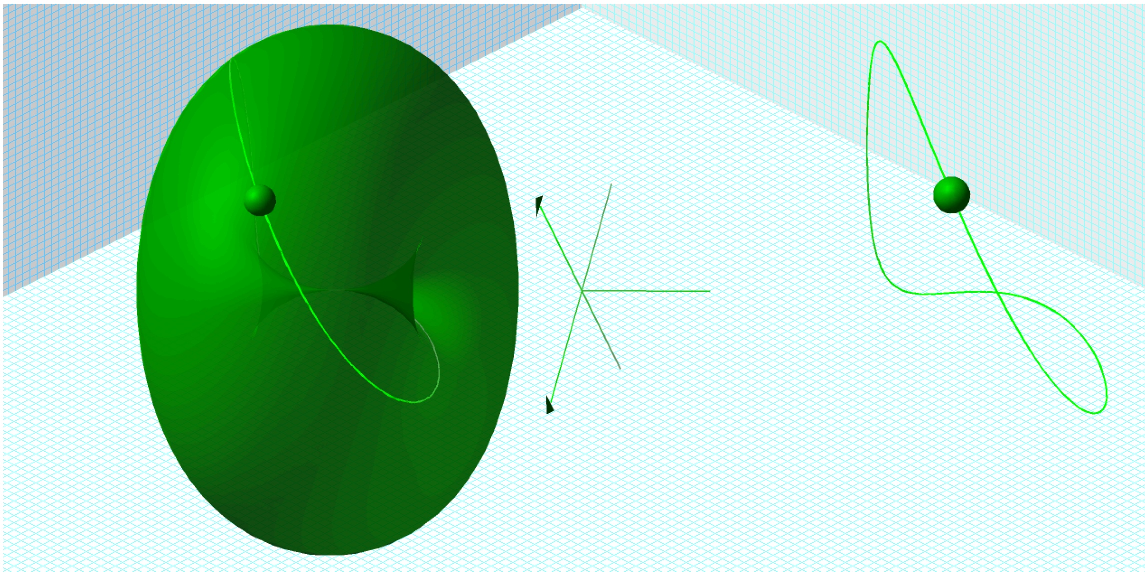

Figure 2. Superluminal half-photon quantum-vortex electron model formed from a superluminal spin-½ charged half-photon model. The superluminal energy quantum moves on the surface of a horn torus with a maximum speed $V_{\max} = c\sqrt{5}$ and a minimum speed $V_{\min} = c$. Figure copyright ©2018 by Richard Gauthier.

The angular momentum or spin of the quantum vortex electron in the *z* or longitudinal direction of motion is calculated by $S_z = R_o \times P_{transverse} = (\lambda_{Compton} / 4\pi) \times (h / \lambda_{Compton}) = h / 4\pi = \frac{1}{2}\hbar$, where $R_o = \lambda_{Compton} / 4\pi$ is the radius of the half-photon's circular closed-helical axis and $P_{transverse} = \frac{1}{2} h / \lambda = \frac{1}{2} h / (\lambda_{Compton} / 2) = h / \lambda_{Compton}$ from equation (4) below is the circling linear momentum of the half-photon of *zitterbewegung* frequency $\nu_{zitt} = 2mc^2 / h$ and wavelength $\lambda = c / \nu_{zitt} = c / (2mc^2 / h) = h / 2mc = \lambda_{Compton} / 2$ forming the quantum-vortex electron model. This calculated spin $S_z = \frac{1}{2}\hbar$ is the experimentally measured longitudinal component of an electron's spin.

The calculated *z*-component of the magnetic moment $\vec{m}$ of the quantum vortex electron model is found to be $m_z = -0.75\mu_B$, where $\mu_B = e\hbar / 2m_e = 9.274 \times 10^{-24}\, J\ T^{-1}$ is the Bohr magneton. See https://en.wikipedia.org/wiki/Bohr_magneton. The quantum vortex's magnetic moment is therefore 75% of the value obtained from the Dirac equation for the electron's magnetic moment. For comparison, the *z*-component of the magnetic moment of an electric charge e moving at light speed in a circle whose circumference is $\frac{1}{2}\lambda_{Compton}$ is found to be $m_z = -0.50\mu_B$. The standard formula used for calculating the magnetic moment of a closed 3-dimensional current loop is

$\vec{m} = \dfrac{I}{2}\displaystyle\int_0^T \vec{r}(t) \times d\vec{r}(t)$ where *T* is the period of one complete cycle.

In the quantum vortex electron model, the electric current is produced by the superluminal energy quantum having charge $-e$ that is moving superluminally in the closed helical trajectory given in equation (3). The z-component of the quantum vortex's magnetic moment, using the above general formula for the magnetic moment $\vec{m}$, becomes

$m_z = -\frac{e}{4\pi}\int_0^{2\pi} x(\theta)Vy(\theta) - y(\theta)Vx(\theta)d\theta$ where $\theta = \omega_{zitt}t$ goes from 0 to 2π in one cycle of the quantum-vortex electron. The details of this magnetic moment calculation are given in the appendix of Gauthier[3].

The double-helix photon equations for electron–positron pair production

During electron-positron pair production from a single photon (when the photon is nearby an atomic nucleus), the photon has to have a minimum energy $E = 2mc^2$ so that it has enough energy to form an electron and a positron each with energy mc^2. The wavelength λ of such a photon is found from $E = 2mc^2 = h\nu = hc/\lambda$ to be $\lambda = h/2mc = \lambda_{Compton}/2$ where $\lambda_{Compton} = h/mc = 2.43\times10^{-12}\,\text{m}$ is the Compton wavelength, which is the wavelength of a photon having energy mc^2. Similarly, the angular frequency ω of a photon with energy $E = 2mc^2$ is found from $\hbar\omega = 2mc^2$ to be $\omega = 2mc^2/\hbar = \omega_{zitt}$ where $\omega_{zitt} = 2\pi\nu_{zitt} = 2\pi\times 2mc^2/h$ is the *zitterbewegung* angular frequency within the Dirac electron, found from the Dirac Equation.

If we insert the values $\lambda = \lambda_C/2$ and $\omega = \omega_{zitt}$ into the position and momentum coordinates of the first half-photon helix given in equation (1) above, we get

$$\begin{aligned}
x_1(t) &= \frac{\lambda_C}{4\pi}\cos(\omega_{zitt}t) & p_{x1}(t) &= -\frac{h}{\lambda_C}\sin(\omega_{zitt}t) \\
y_1(t) &= \frac{\lambda_C}{4\pi}\sin(\omega_{zitt}t) & p_{y1}(t) &= \frac{h}{\lambda_C}\cos(\omega_{zitt}t) \\
z_1(t) &= ct & p_{z1}(t) &= \frac{h}{\lambda_C}
\end{aligned} \tag{4}$$

The amplitude $\lambda_C/4\pi$ and angular frequency ω_{zitt} of each of the superluminal half-photons in equation (4) in the double-helix photon model of energy $E = 2mc^2$, and the equal helical radius $\lambda_C/4\pi$ and angular frequency ω_{zitt} of the superluminal half-photon quantum-vortex electron model in equation (3) strongly suggests that each of the half-photons of the double-helix photon model with total energy $E = 2mc^2$

can, in the process of electron-positron pair production, separate from the other half-photon. The separated half-photon can then curl up its half-photon helical trajectory into a closed helix with the same helical radius $\lambda_C / 4\pi$ and same angular frequency ω_{zitt}. This circular axis of this closed helix has a circumference of length equal to 1 half-photon wavelength $\lambda = \lambda_C / 2$ and radius $R = \lambda_C / 4\pi$. This is the orbital radius required to give an electron model composed of a circling photon-like object of linear momentum $p = h / \lambda_C$ from equation (4) the required spin $s = R_o \times p = (\lambda_C / 4\pi) \times (h / \lambda_C) = h / 4\pi = \frac{1}{2}\hbar$ of an electron. Each superluminal spin-½ half-photon from a double-helix photon model having just the right energy $E = 2mc^2$ for producing an electron-positron pair, can curl up its helical trajectory and, without changing its amplitude $\lambda_C / 4\pi$ or angular frequency ω_{zitt}, produce the electron and positron superluminal half-photon quantum vortex models described by equation (3) above.

Figure 3 shows a double-helix photon coming in from the left, with its two helically-circulating positively (red) charged and negatively (green) charged superluminal energy quanta moving at speed $c\sqrt{2}$. The charge values are $Q = \pm e\sqrt{2/\alpha} = \pm 16.6e$. When passing near an atomic nucleus (not shown), each of the two charged superluminal quanta lose all but $\pm 1e$ of their electric charge to the opposite charge. Due to their instability when separated from the other charge, the spin-½ half-photons curl up their trajectories to become a superluminal half-photon quantum-vortex electron and positron, which move off at an angle to the right, away from where they were formed.

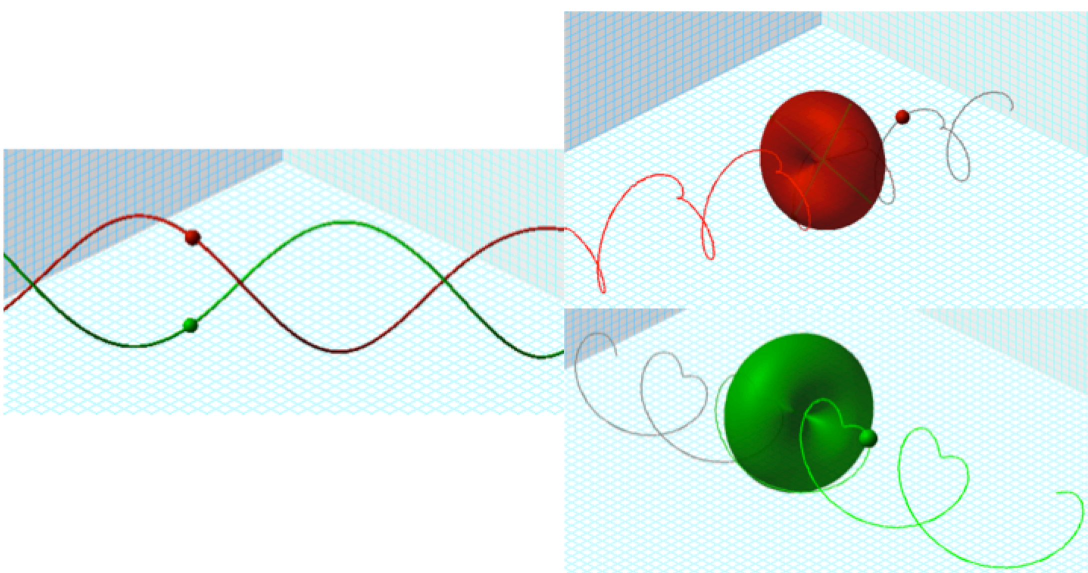

Figure 3. The two superluminal energy quanta forming half-photons in the double-helix photon model separate when passing near an atomic nucleus (not shown) and each superluminal half-photon's helical trajectory curls up to form a superluminal half-photon quantum-vortex electron and positron which move away from their region of formation. Figure copyright ©2018 by Richard Gauthier.

The quantum vortex electron model for relativistic electrons

The quantum-vortex model of a resting electron above is derived from an incoming double-helix photon model having the minimum energy $E = 2mc^2$ to form two quantum vortex resting electrons each of rest energy $E_o = mc^2$. But electron-positron pair creation also occurs with incoming photon energies much greater than $E = 2mc^2$. In this case an electron-positron pair is created that is moving relativistically. The electron and positron produced may each have energy $E = \gamma mc^2$. How is the energy structure of a quantum vortex electron changed if it is moving at relativistic (or even non-relativistic) velocities rather than being at rest? Of course, the superluminal energy quantum composing the quantum vortex electron is moving superluminally even in a resting electron (having speed $v = 0$).

The answer to this question about relativistic electron-positron pair production was partly anticipated in two earlier articles (Gauthier[4] and Gauthier[5]). The first article proposed a relativistic electron model composed of a circulating spin-½ charged photon (not half-photon). The spin-½ charged photon was thought to be required so that the electron model would keep its spin ½ at relativistic velocities and not just spin ½ for a resting or slow-moving electron, which a spin-1 photon circling with a radius $R_o = \lambda_{Compton} / 4\pi = \hbar / 2mc$ could produce. The "generic" relativistic spin-½ charged-photon electron model of Gauthier[4] (which only describes the helical-axis trajectory of a "generic" light-speed spin-½ charged-photon model composing the relativistic electron model) was already in place and can accommodate the spin-½ charged half-photon model composing the quantum-vortex electron model.

There were strong theoretical objections to the idea of a spin-½ charged photon composing an electron (because a photon is uncharged and has spin 1 and not spin ½.) I explained then that a spin-½ charged photon might be a new variety of photon. Then I modified an earlier superluminal spin-1 single-helix photon model (in Gauthier[3]) and proposed a superluminal spin-½ single-helix photon model (in Gauthier[5]) having helical radius $\lambda / 4\pi$, which is half the helical radius $\lambda / 2\pi$ of the spin-1 single-helix photon model. The new spin-½ photon model kept the spin-1 photon model's superluminal speed $c\sqrt{2}$ and its 45-degree helical trajectory. The new spin-½ photon model, because of its smaller helical radius $\lambda / 4\pi$, has to make two helical loops per photon wavelength λ in order to have spin ½ instead of spin 1. This spin-½ photon model of Gauthier[5] was proposed for incorporation into the "generic" relativist spin-½ electron model of Gauthier[4]. When this electron model is at rest, the circling spin-½ photon makes two loops per Compton wavelength, and therefore loops at the *zitterbewegung* frequency $\nu_{zitt} = 2mc^2 / h$ within the electron model. But the problem of destructive 180-degrees-out-of-phase self-interference after the first loop of the double-looping Compton-wavelength photon remained, as in non-superluminal electron models composed of a double-looping Compton-wavelength photon-like object.

Then, when I learned about de Broglie's 1930's spin-½ half-photon hypothesis for a composite photon, I realized that two of my spin-½ photon models could be converted into two oppositely-charged spin-½ half-photon models composing a double-helix photon model. The frequency (and wavelength) of the double-helix photon model would be the same as the frequency (and wavelength) of the two spin-½ half-photons composing the double helix photon model. Then I realized that my former spin-½ photon model with two loops per wavelength could now be considered to be two half-photons with each half-photon having a frequency of one loop or one cycle per wavelength, and following the wavelength-frequency relationship $c = \lambda \nu$. The radius of each of the half-photons would still be $R = \lambda / 2\pi$, the same as the radius of the double-helix photon model. A double-helix photon of energy $E = 2mc^2 = h\nu$ (which is the energy of a photon that can be converted into an electron-positron pair) would have frequency $\nu = 2mc^2 / h = \nu_{zitt}$. This double-helix photon would have the *zitterbewegung* frequency associated (through the Dirac equation) of a single electron or positron. The wavelength λ_{zitt} of this *zitterbewegung* double-helix photon is $\lambda_{zitt} = c / \nu_{zitt} = c / (2mc^2 / h) = h / 2mc = \lambda_{Compton} / 2$. Its radius would be $R = \lambda / 2\pi = \lambda zitt / 2\pi = (\lambda_{Compton} / 2) / 2\pi = \lambda_{Compton} / 4\pi = R_o$. Both spin-½ charged half-photons in the double-helix photon model have this same radius $R_o = \lambda_{zitt} / 2\pi = \lambda_{Compton} / 4\pi$, which is also the radius of the helical axis in the proposed quantum vortex electron model.

The quantum-vortex electron model is based on the spin-½ charged photon model in Gauthier[4] but the spin-½ charged photon is replaced by a spin-½ charged half–photon model whose frequency is the *zitterbewegung* frequency $\nu_{zitt} = 2mc^2 / h$ and whose wavelength is $\lambda_{zitt} = c / \nu_{zitt} = \lambda_{Compton} / 2$. The energy of the spin-½ half-photon composing the quantum vortex electron model is $E_o = mc^2$ because it has half the energy of the double-helix photon of energy $E = 2mc^2$ that can produce and electron-positron pair.

The relativistic quantum-vortex electron model therefore combines the "generic" relativistic spin-½ charged-photon electron model described in Gauthier[4] with the superluminal spin-½ photon model described in Gauthier[5], except that the superluminal spin-½ photon model which has two helical loops or cycles per photon wavelength becomes a spin-½ charged half-photon model with only one loop or cycle per half-photon wavelength. The resting quantum-vortex electron model is composed of a circling a spin-½ half-photon model of energy $E_o = mc^2$, internal frequency $\nu_{zitt} = 2mc^2 / h$, and helical radius $R_o = \lambda_{Compton} / 4\pi$. This spin-½ charged half-photon moves along a circular axis of radius R_o corresponding to a circle of circumference $C = 2\pi R_o = \lambda_{Compton} / 2$, which corresponds to the quantum-vortex electron's internal *zitterbewegung* frequency $\nu_{zitt} = 2mc^2 / h$. In the quantum-vortex electron model, $E_o = mc^2$ is the energy and $\nu_{zitt} = 2mc^2 / h$ is the frequency of the spin-½ half-photon coming from a double-helix photon model of energy

$E = 2E_o = 2mc^2$, frequency $\nu_{zitt} = 2mc^2 / h$, wavelength $\lambda_{Compton} / 2$ and helical radius $\lambda_{Compton} / 4\pi$. The spin-½ charged half-photon composing the quantum-vortex electron model has half the energy but the same frequency, wavelength and helical radius as its corresponding double-helix photon.

When the quantum-vortex electron model moves at relativistic velocities, the helically circulating spin-½ photon's wavelength (which is $\lambda_{Compton} / 2$ in the resting quantum-vortex electron model) is inversely proportional to the spin-½ half-photon's energy $E = \gamma mc^2$. The spin-½ charged half-photon's wavelength decreases as $\lambda = \lambda_{Compton} / 2\gamma$ as the spin-½ charged half-photon's energy becomes $E = \gamma mc^2$. The helical radius R_{helix} of the helically moving superluminal energy quantum of the circling spin-½ photon decreases correspondingly as $R_{helix} = \lambda / 2\pi = \lambda_{Compton} / 4\pi\gamma = R_o / \gamma$.

A moving or relativistic quantum-vortex electron model with velocity *v* has, as in Gauthier[4], its helical axis moving in an open helical trajectory of radius $R = \lambda_{Compton} / 4\pi\gamma^2 = R_o / \gamma^2$ rather than moving in a circle of radius $R_o = \lambda_{Compton} / 4\pi$ in the resting quantum-vortex electron. The relativistic quantum-vortex electron has energy $E = \gamma mc^2$. Its frequency ν will be $\nu = \gamma\nu_{zitt}$ and its wavelength will correspondingly become $\lambda = c / \nu = c / \gamma\nu_{zitt} = c / (2\gamma mc^2 / h) = h / 2\gamma mc = \lambda_{Compton} / 2\gamma$. The helical radius of the circulating half-photon will become $R_{helix} = \lambda / 2\pi = \lambda_{Compton} / 4\gamma\pi = R_o / \gamma$

In the relativistic quantum-vortex electron, the spin-½ charged half-photon moves along an open helical axis of helical radius $R = R_o / \gamma^2$ (as also explained in Gauthier[4]) rather than moving in a circle of radius R_o as in a resting quantum-vortex electron model. This rather surprising result comes from special relativity and the geometry of the helical axis of the moving spin-½ charged half-photon. The open-helix trajectory of the spin-½ half-photon's helical axis in a relativistic quantum-vortex electron model is the result of the transverse circular speed of the spin-½ photon within the electron model, combined with the longitudinal speed *v* of the moving electron model itself. These combined motions of the spin-½ half-photon composing the relativistic quantum-vortex electron model gives the spin-½ half-photon an open helical axis along which it moves with speed *c*. The speed *c* of the helically-circulating half-photon along its helical axis in a moving or relativistic quantum-vortex electron model is the same as the speed *c* of the helically-circulating charged half-photon moving along a circular trajectory in a resting quantum vortex electron model. This is because, according to special relativity, the speed of light is constant, independent of the rest frame in which the speed of light is measured. In the relativistic electron model, while the spin-½ half-photon moves forward along this helical-axis trajectory with velocity c, the longitudinal component of this rotating velocity *c* is *v*, the speed of the relativistic quantum vortex electron model itself. The forward helical angle θ of the helical-axis trajectory is given by

$\cos\theta = v/c$. The wavelength of the spin-½ half-photon moving along this helical axis trajectory is contracted (as seen above) by a factor of γ due to the increased energy of the spin-½ charged photon forming the moving quantum vortex electron model. This helical axis now makes one full helical turn for each γ -contracted wavelength. The circumference $2\pi R$ of this helical axis is equal to the γ -contracted half-photon wavelength times $\sin\theta$. This is because geometrically, if this helical axis is mathematically rolled out flat, the rolled-out γ -contracted wavelength $\lambda_{Compton}/2\gamma$ is the hypotenuse of a rolled-flat triangle whose hypotenuse makes the angle θ with the longitudinal direction of motion of the electron model. The side of the triangle opposite θ is the rolled-out helical circumference $2\pi R$. Since $\cos\theta = v/c$ implies that $\sin\theta = \sqrt{1-v^2/c^2} = 1/\gamma$, this gives $2\pi R = (\lambda_{Compton}/2\gamma)\sin\theta = (\lambda_{Compton}/2\gamma)\times(1/\gamma) = \lambda_{Compton}/2\gamma^2$, which gives the helical axis's helical radius as $R = \lambda_{Compton}/4\pi\gamma^2 = R_o/\gamma^2$. This is also explained in Gauthier[4].

A photon having energy enough to produced a relativistic electron and positron each with $E = \gamma mc^2$ must clearly have energy $E = 2\gamma mc^2$. Electron-positron pair production generally occurs near an atomic nucleus, which absorbs a small amount of momentum in the process. The amount of kinetic energy absorbed by the atomic nucleus during electron-positron pair production is almost insignificant due to the relative mass of an atomic nucleus compared to the mass of an electron. In any case this will not affect the present discussion.

In the double-helix photon model, each of the spin-½ half–photons composing an $E = 2\gamma mc^2$ photon will have half of this total energy, or $E = \gamma mc^2$ for each spin-½ half–photon that will become an electron or positron. The frequency of this $E = 2\gamma mc^2$ photon is given by $E = 2\gamma mc^2 = h\nu$, or $\nu = 2\gamma mc^2/h = \gamma\nu_{zitt}$ where $\nu_{zitt} = 2mc^2/h$ is the *zitterbewegung* frequency of the Dirac electron. Each of the spin-½ charged half-photons retains this energy $E = \gamma mc^2$ and frequency $\nu = \gamma\nu_{zitt}$ in the relativistic quantum vortex electron that is formed from this spin-½ charged photon.

The wavelength of the $E = 2\gamma mc^2$ photon forming and electron-positron pair is given by $E = 2\gamma mc^2 = h\nu = h/\lambda$. This gives $\lambda = h/2\gamma mc = \lambda_{Compton}/2\gamma$ where $\lambda_{Compton} = h/mc = 2.426\times10^{-12}$ m is the Compton wavelength for an electron. Each of the spin-½ half-photons composing this double-helix photon of energy $E = 2\gamma mc^2$ has the same wavelength $\lambda = \lambda_{Compton}/2\gamma$ as this double-helix photon.

The radius R of the double-helix photon of energy $E = 2\gamma mc^2$ is given by $R = \lambda/2\pi = (\lambda_{Compton}/2\gamma)/2\pi = \lambda_{Compton}/4\pi\gamma = R_o/\gamma$ where $R_o = \lambda_{Compton}/4\pi = \hbar/2mc$.

Each spin-½ charged photon from this $E = 2\gamma mc^2$ double-helix photon therefore has the frequency $\nu = \gamma \nu_{zitt}$, the wavelength $\lambda = \lambda_{Compton} / 2\gamma$ and the helical radius $R_{helix} = R_o / \gamma = \lambda_{Compton} / 4\pi\gamma$ that is found in the relativistic electron and relativistic positron described earlier for the relativistic quantum-vortex model of the electron. So there is no difference between the energy, the frequency, the wavelength or the helical radius of each spin-½ charged half-photon that is part of the double-helix photon of energy $E = 2\gamma mc^2$, and the energy, frequency, wavelength and helical radius of the spin-½ charged half-photon composing the relativistic quantum-vortex electron or positron model. Each spin-½ charged half-photon in an $E = 2\gamma mc^2$ double-helix photon has a straight helical axis. The relativistic spin-½ charged half-photon in the relativistic quantum vortex electron and positron follows a helical axis trajectory (described in Gauthier[4]) whose radius R is given by $R = R_o / \gamma^2 = \lambda_{Compton} / 4\pi\gamma^2$. This helical axis trajectory has a forward helical angle θ given by $\cos\theta = v / c$, where v is the linear velocity of the relativistic quantum-vortex electron or positron model as a whole, and c is the light-speed velocity of the spin-½ charged half-photon on its helical-axis trajectory. See Figure 4 below, taken from from Gauthier[4]. Figure 4 shows the helical trajectory with forward angle θ of a spin-½ charged half-photon composing a relativistic quantum-vortex electron, compared to the horizontal linear velocity and linear momentum of the relativistic quantum-vortex electron itself. The term "charged photon" in the figure should now be understood as "charged spin-½ half-photon".

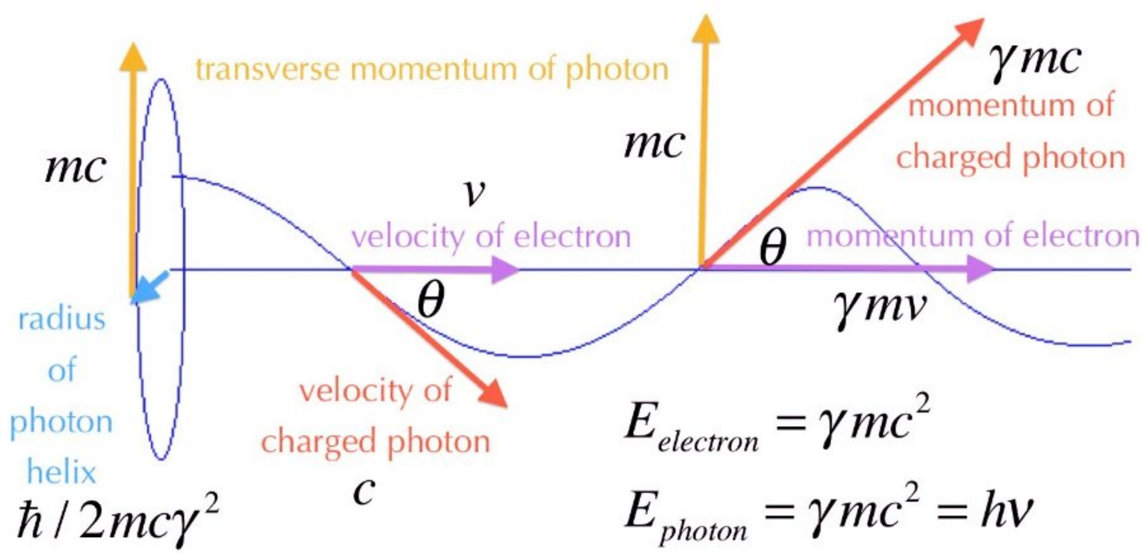

Figure 4. The figure shows the helical trajectory with forward angle θ of the charged spin-½ half-photon in a relativistic quantum-vortex electron. The figure is from from Gauthier[4]. The term "charged photon" in the figure should now be understood as "charged spin-½ half-photon". The figure shows the velocity *c* and the helically-circulating momentum γmc of the charged spin-½ half-photon along its open-helical axis, and the horizontal velocity *v* and the relativistic momentum γmv of the relativistic quantum-vortex electron as a whole. Nothing superluminal is shown in this diagram. Figure copyright © 2018 by Richard Gauthier.

Discussion

Both the photon and the electron are very stable quantum particles that can exist for billions of years in the universe if they do not meet with other particles that absorb or transform them. This article considers a double-helix model of a stable photon that then interacts with a nearby atomic nucleus and forms quantum-vortex models of a stable electron-positron pair. The connecting "link" between the photon and electron models is a proposed electrically-charged superluminal energy quantum that composes the photon model and the electron and positron models. The double-helix photon model, composed of two superluminal charged spin-½ half-photons, separates to form a quantum-vortex model of an electron and a positron. The electron and positron models are composed of a charged spin-½ half-photon from the double-helix photon, although the magnitude of charge changes in this process.

The trajectory of a single open-helix half-photon may be unstable. Two oppositely charged half-photons are necessary to form a composite photon with a stable double-helix trajectory. But one individually-unstable charged single-helix half-photon may, when the photon passes near an atomic nucleus, become separated from its counterpart half-photon. Then each half-photon may have no other physical option than to curl up its open-helical trajectory to form an electron or a positron model whose half-photon moves along a closed helical trajectory. This closed-helical trajectory of the half-photon composing the electron model could MINIMIZE the half-photon's instability as a self-stabilizing quantum vortex forming the electron or positron model. An electron is a stable particle because it has no other physical options (except to join with a positron to become a positronium atom that then transforms into two, three or more photons) without violating conservation of momentum, conservation of energy, conservation of charge or any other conservation law that is considered inviolable for fundamental particles. The inability of a single curled-up single-helix superluminal half-photon from a double-helix photon to spontaneously transform itself into one or more other particles is what gives the electron its stability to exist for billions of years.

Now consider that a sufficiently energetic double-helix photon passing near an atomic nucleus can divide into two superluminal single-helix half-photons that form a higher mass muon-antimuon pair or an even higher mass tau-antitau pair. The muon and the tau are both in the electron's family and so should have a similar internal energy structure as that of the electron. The muon and the tau could each be composed of a higher-energy curled-up superluminal single-helix charged half-photon. Unlike the electron, however, the muon and the tau ARE spontaneously unstable. A negative muon can spontaneously decay into an electron, a muon neutrino and an electron antineutrino without violating any physical conservation laws. See https://en.wikipedia.org/wiki/Muon. So the unstable muon can and does decay into more stable particles.

Also see https://en.wikipedia.org/wiki/Electron : "There are elementary particles that spontaneously decay into less massive particles. An example is the muon, with a mean lifetime of 2.2×10^{-6} seconds, which decays into an electron, a muon neutrino and an electron antineutrino. The electron, on the other hand, is thought to be stable on theoretical grounds: the electron is the least massive particle with non-zero electric charge, so its decay would violate charge conservation. The experimental lower bound for the electron's mean lifetime is 6.6×10^{28} years, at a 90% confidence level."

The more massive and also unstable tau can spontaneously decay in a variety of ways into other less-massive particles without violating accepted conservation laws. See https://en.wikipedia.org/wiki/Tau_(particle) . But the electron can't decay into anything else without violating physical conservation laws, charge conservation in particular. This makes the electron de facto a stable particle, even if it is composed of a potentially-unstable charged single-helix half-photon.

In this single-helix half-photon approach to particle composition, the electron can be considered to be the "ground state" of the electron-muon-tau family. Just as an atomic electron in its ground state does not radiate energy, the electrically-charged superluminal closed-helix electron model does not radiate energy due to its stabilized internal helical quantum-vortex motion. Moving in a closed helix of circular axis length $\lambda_{Compton}/2$ and with a *zitterbewegung* frequency $\nu = 2mc^2/h$, the circulating half-photon forming an electron is self-stabilizing and has no allowed lower energy state. The muon and tau are similarly self-stabilized in their own internal $\lambda_{Compton}/2$ circular orbits, where $\lambda_{Compton} = h/mc$ is calculated using the larger mass of the muon or the still-larger mass of the tau. These two particles can both decay to lower energy states without violating conservation laws.

So considering what may happen to a single superluminal single-helical half-photon from a double-helix photon during pair-production sheds light on how an individually unstable half-photon can form a stabilized half-photon particle (an electron) or an unstable half-photon particle such as a muon or a tau.

In this model of a double-helix photon producing a quantum-vortex electron-positron pair, there is a change of the positive or negative charge $Q = e\sqrt{2/\alpha} = 16.6e$ on each spin-½ charged half-photon composing the double-helix photon model, compared to the charges –*e* and +*e* on an electron and a positron. During electron-positron pair production, the charge magnitude $Q = 16.6e$ on the spin-½ half-photon drops to the charge -*e* on the electron and +*e* on the positron. The quantity α is the fine structure constant $\alpha = 1/137.04$ in quantum electrodynamics (QED). It appears in the double-helix photon model in the calculation of the electric charge required to maintain a stable double-helix model (see Gauthier[1]) held together by Coulomb attraction. It should be remembered that a sufficiently energetic photon can produce many other types of particle-antiparticle pairs, such proton-antiproton pairs and neutron-antineutron pairs. So there may not be complete continuity between the trajectory of the spin-½ charged half-photon while coming from the double-helix photon to become the quantum-vortex electron. Similarly, when an electron and a positron mutually annihilate, they can produce two, three or more photons. According to the double-helix photon model, each photon produced by electron-positron annihilation would be composed of a pair of spin-½ charged photons, only one pair of which could have composed the electron and the positron that mutually annihilated. So there is much room for further research on the double-helix photon model and the quantum-vortex electron and other particle models.

Conclusions

The proposed superluminal double-helix photon model may be transformed relatively seamlessly into a superluminal single-helix quantum-vortex model of an electron and a positron. The energy of each spin-½ half-photon in a sufficiently energetic double-helix photon can become the energy of one quantum-vortex electron or positron. The parameters of energy, frequency, wavelength and helical radius of each spin-½ half-photon composing the double-helix photon remain the same in their transformation into the electron and positron quantum-vortex models. These photon and electron models clearly oversimplify the process of electron-positron pair production from a sufficiently energetic photon. The superluminal aspect of both models may challenge ideas about the speed of light. However, the double-helix photon model and the quantum-vortex electron model are both only internally superluminal. The double-helix photon model still travels forward at light-speed *c*, while the quantum-vortex model of the electron as a whole travels forward always at less than light-speed *c*. The proposed superluminal energy quantum and its associated quantum wave and particle properties in photons, electrons and other particles may challenge conventional ideas about light. Still, the quantitative parameter constancies of the proposed spin-½ charged half-photon as it is transformed from a double-helix photon into a quantum-vortex electron or positron suggest that this transformation process and the reverse transformation process of particle-antiparticle annihilation into photons may be modeled in a more continuous way that gives some deeper insight in to this fundamental process of converting light into matter.

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Appendix: Parametric equations for 3D graphing of the superluminal half-photon quantum vortex electron model.

The parametric equations for the *x*, *y* and *z*-coordinates of the position and movement of the superluminal energy quantum composing the superluminal half-photon quantum-vortex electron model in equation (3) can be graphed in three dimensions with various 3D graphing programs. The figures in this article use the 3D graphing program Graphic Calculator available from Pacific Tech at http://www.pacifict.com. The range of the variables *x, y, z, n, t, v* and *u* need to be set appropriately in the graphing program. The three sets of parametric equations below correspond to the three 3D models listed below. The models can be displayed separately or superimposed by selecting the color in the box at the left of each set of equations, or leaving the box white.

1) The animation of the moving superluminal energy quantum
2) The closed helical trajectory of the superluminal energy quantum for a resting electron
3) The horn torus on which the superluminal energy quantum is moving along its closed helical trajectory in a resting electron.

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} (1+\cos 2\pi n)\cos 2\pi n \\ (1+\cos 2\pi n)(\sin 2\pi n) \\ \sin 2\pi n \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} (1+\cos 2\pi t)\cos 2\pi t \\ (1+\cos 2\pi t)(\sin 2\pi t) \\ \sin 2\pi t \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} (1+\cos 2\pi v)\cos(2\pi u) \\ (1+\cos 2\pi v)\sin(2\pi u) \\ \sin 2\pi v \end{bmatrix}$$

Richard Gauthier
Department of Chemistry and Physics
Santa Rosa Junior College
1501 Mendocino Avenue
Santa Rosa, California 95401, USA
richgauthier(at)gmail.com,