A QED-Compatible Wave Theory of Light, Electrons, and their Interactions

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ABSTRACT

The photoelectric effect, the Compton effects, and now anticorrelation experiments have been claimed to prove that light consists of particles flying through a void. However the particle model is decisively falsified by the known wave-qualities of electromagnetic radiation. Quantum Electrodynamics also uses spreading wave amplitudes; not flying particles. The evidence indicates that light is a wave and electrons are electromagnetic wave-structures that absorb and emit light in discrete wave-packets. These wave-quanta are emitted directionally and then spread in space in proportion to their wavelength. Their waves superposition with all other waves in space. In low intensity experiments, the waves that an electron in a photodetector absorbs come from the superpositioning of the source wave-quanta and background radiation. The importance of background radiation is evidenced by "dark counts". Treating electrons and the quanta they absorb and emit as particles when they are composed of waves is the source of all the paradoxes, unreality and confusion in Quantum Mechanics. The word "photon" should be replaced by "quantum" in the description of this particular electronic process. The conceptual model presented here explains the known phenomena without producing paradoxes and unifies quantum and classical electromagnetics.

Keywords: anticorrelation experiments, electron, photoelectric effect, photon, Planck's constant, quanta, Quantum Electrodynamics, waves

1. THE BIRTH OF THE PHOTON

In 1896, most physicists believed that light was a wave in a medium: the electromagnetic ether. The wave theory was necessary to explain everything that was known about light: wavelength and frequency, invariant velocity independent of source velocity, diffraction, and superpositioning. Thirty years later a dramatic shift had occurred; most physicists agreed that light was a particle. In the interim, they had discovered several phenomena in the microscopic world that could not be explained by their existing classical models of matter and light. The radiant energy exchanged among atoms in a blackbody was found to be quantized. X-rays and gamma rays appeared not to spread in space; the entire quanta of energy released by some atoms appeared to be taken up by other atoms at some distance with no time lag. A similar phenomenon was observed with visible light in the photoelectric effect. In addition, the amount of electromagnetic energy imparted to an electron was determined only by the frequency of the radiation, not by the intensity. In the Compton effect, x-ray frequencies conserved linear momentum in their interactions with electrons, suggesting a collision of particles. In 1923, Louis de Broglie theorized that both light and matter had both wave and particle characteristics; that the photon, electron, and every other fundamental object was a particle somehow associated with a wave.

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During this interim a new epistemology had taken root in physics, an epistemology that is not fully understood to this day. Positivism was derived from Bishop Berkeley's subjective idealism and Ernst Mach's sensationalism. It attempted to eliminate all hypothetical entities from physics by reducing physics to the description and prediction of the sensations and measurements of the observer. It abandoned the task of theorizing about what exists and what causes the observations.[1] In 1905 Albert Einstein imposed his own version of this epistemology upon physics with his papers on Special Relativity and the lightquantum. In Relativity, he related motion and its effects to observers and arbitrary frames instead of Cosmic entities or frames. With his lightquantum theory he reduced light to what could be seen and measured in high-frequency experiments—its quantized interactions with electrons. Relativity and the light-quantum eliminated the ether (space as substance) from physics; not by proving that space was void, but by restricting physics to the description of the observers' experiences.

By 1926 most physicists had accepted this Machian-Einsteinian program for physics. They agreed that light was composed of particles even though no light particle had ever been observed and the particle theory was contradicted by the known wave-qualities of light. They sought to resolve the contradiction by giving it a name, "wave-particle duality". They have not resolved the contradiction by creating a better theory. This is the source of all the unreality, paradox, and confusion that characterizes Quantum Mechanics today. We must replace "wave-particle duality" with a working theory that explains exactly how, when, and why light and electrons can appear to be particle-like or appear to be wave-like. We must create a coherent physical theory of light and electrons to supersede both antiquated models: the classical and the observer-based.

2. QUANTUM ELECTRODYNAMICS

The success of Quantum Electrodynamics (QED) is offered as proof that light is composed of flying particles, now called "photons". However, in his book, *QED*,[2] Richard Feynman demonstrates that QED is only an accounting system for the prediction of observable photonic "events"—quantized, photomultiplied interactions between light and electrons.[3] QED describes the observer's measurements. It is not a physical theory *per se*: it does not attempt to explain what light and electrons are, nor how they interact as they do. Feynman explains that radiation sources produce not real waves, but wave-like probability amplitudes whose propagation and superpositioning can be used to predict observable electronic absorptions—photomultiplier clicks.[4] These probability amplitudes follow the Huygens-Fresnel principle: they spread by spherical wavelets from every portion of the wave front. Feynman restates this principle as "light has a probability to go everywhere".[5] In QED, the wave-like probability amplitudes spread in all directions, shrinking in size according to the inverse square law and rotating in space according to their frequency. This wave-behavior is described as "shrinks and turns" of amplitude arrows. Adding up the resultant arrows for all possible paths to a given point in space yields the final probability amplitude at that point. The square of the amplitude represents the probability that a quantized light-matter interaction will be observed at a given location and time. This wave-model is consistent with light being a physical wave in space. For all kinds of waves, the square of the amplitude yields the intensity (rate of energy flow). In QED, where the intensity is greatest is where light-matter reactions are most likely to occur.

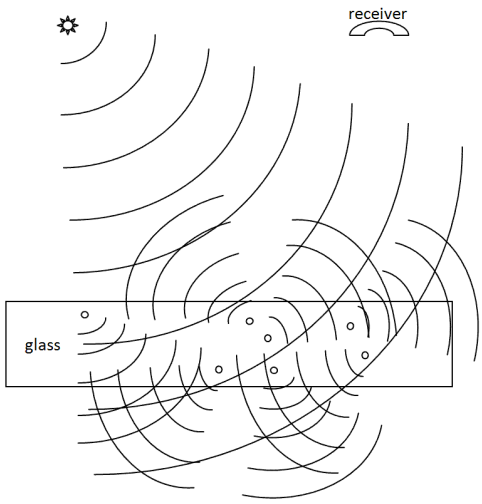

Figure 1. In Feynman's QED wave-model, source amplitudes are absorbed and then re-emitted in all directions by electrons within the glass. To find the probability of an absorption-event at the receiver, one must sum the wave-like amplitudes from all possible paths.

Since QED models spreading waves, not flying particles, its success supports the wave theory of light. Feynman admits that there is no flying photon in QED; that QED says only that a photon has an amplitude to go this way and an amplitude to go that way, and where the amplitudes oppose each other, no photon will go.[6] Even though Feynman understands that it is absurd to ask "which way the photon goes", he often finds himself thinking in those terms. Realizing that the flying photon makes no sense as a physical hypothesis, Feynman concludes that Nature is absurd,[7] and so physics has given up on trying to find physical models to explain the phenomena.[8] (When Nature does not make sense, perhaps we should question our approach.) He admits that wave theory can explain almost all the phenomena treated by QED, but claims that "wave theory cannot explain how the (photomultiplier) detector makes equally loud clicks as the light gets dimmer."[9] He concludes that "light is made of particles".[10] That conclusion does not follow from the facts. This same confusion is still evident in a recent review article. After presenting arguments for the existence of flying photons and describing photons as if they are real particles, the authors admit that QED only predicts the probability of detection events and that we should not take the idea of a photon or wave too seriously; "the quantum state is simply a tool to calculate probabilities…whenever we talk about a particle, or more specifically a photon, we should only mean that which a 'click in the detector' refers to.[11]

It is evident that Feynman and subsequent physics have not fully understand the epistemology of Quantum Electrodynamics. It deals only with the "observer's information". It models the observer's experiences and lacks objective physical-theoretical content.[12] On the contrary, physicists want to understand the Cosmos; they are thus trapped in a conflict between the epistemology of QED and their desire for a working physical theory of light.

3. WAVE OR PARTICLE?

In order to understand Nature, we must reject contradictory notions like "wave-particle duality". The word "photon" is ambiguous as it is used both to describe flying particles and spreading wave-packets. The questions are: does the light emitted from an individual electron consist of a flying particle, or of a wave-packet. If it is a wave packet, does it spread in space like all waves? Is the quantum of light absorbed by an electron the same particle or wave-packet that was emitted by another electron, or is it a product of the superpositioning of spread-out, reduced-amplitude wave-packets from the source with

background electromagnetic (EM) waves? To answer these questions we must first review the evidence and decide which fundamental theory is the better one:

1. **Wave Theory**—Light is a spreading wave in an electromagnetic medium
2. **Particle Theory**—Light is a discrete particle flying through a void

These theories are logically and physically incompatible. They imply starkly different properties. Waves spreading through a substrate will have a constant velocity that is independent of its source's velocity. They will manifest all the qualities of waves. A particle, on the other hand, is a localized, unchanging microscopic entity flying through a void. deciding which model corresponds to the evidence should be easy. Let us compare these competing theories with the known phenomena:

Table 1. **Wave-Particle Truth Table**

Explains or can accommodate:	**Wave Theory**	**Particle Theory**
Wavelength and frequency	Yes	No
Invariant velocity independent of source velocity	Yes	No
Huyghens-Fresnel spreading, diffraction	Yes	No
Superposition, interference	Yes	No
Continuous spectrum (including radio waves)	Yes	No
Light of "subphotonic" amplitude	Yes	No
Laser	Yes†	Yes*
Blackbody spectrum	Yes†	Yes*
Photoelectric effect	Yes†	Yes*
Compton effect	Yes†	Yes*
Photoelectronic anti-correlation experiments	Yes†	Yes*
Quantum Electrodynamics' computational method	Yes†	Yes*

†Requires light-electron interactions to be quantized, and requires unknown background radiation
*Requires wave theory to model and predict quantized events

The truth table demonstrates that, as a physical hypothesis, the particle-in-void theory of light is a non-starter. It is contradicted by known aspects of light and is therefore falsified. Particles flying through a void simply cannot account for many of the best-known qualities of EM radiation. A particle in a void should travel at any velocity; its velocity should vary with the velocity of its source. On the contrary, light's velocity is invariant and independent of its source's velocity. Particles cannot have wavelength and frequency and cannot spread or diffract; these are qualities of waves. Particles cannot exist in the same place at the same time. They must either stick together, mutually annihilate, or collide and rebound. Light waves can exist in the same place at the same time, superimpose, and pass right through each other unchanged. Light waves can be filtered to arbitrarily small energies including "subphotonic" energies—indivisible particles cannot be subdivided by definition. Double slit experiments with low-intensity light contradict the particle theory. Only waves can spread, pass through two slits simultaneously and create an interference pattern—particles cannot. The particle theory also has no possible relation to the continuous spectrum of EM radiation including radio waves that are hundreds of meters long. The particle model of light arose because electrons absorb and emit light in wave-quanta whose energy depends on frequency alone. Even here, the particle model does not work. QED requires wave-theory to model light's velocity, spreading, diffraction, and superpositioning. So light must be a spreading wave can have quantized interactions with electrons. How can we explain the particle-like behaviors of these wave-quanta? Can a wave-model of quanta explain all observed light-matter interactions?

4. THE PHOTOELECTRIC EFFECT

Early in the 20th century, the classical model of light-matter interaction was "Thomson scattering"—EM waves caused atoms or electrons to oscillate and their oscillations produced more waves. This is indeed what happens at longer wavelengths and is the working principle behind many phenomena. However, in the case of radiation within a blackbody this model predicted an "ultraviolet catastrophe" at high frequencies that did not occur. Max Planck realized that he could resolve the problem by treating the EM energy exchanged among electrons as if it were a discrete variable instead of a continuous variable. As the simplest possible fit for the data, he obtained $\Delta E = hf$, where h was a proportionality constant describing this quantized interaction of radiation and matter. Planck believed that the light-matter interaction was quantized, not light itself. We know today that blackbody EM energy exchange at higher frequencies is not due to oscillations of entire atoms or electrons, but to the actual absorption and re-emission of light by bound and free electrons. This fact lends further support to Planck's contention that the quantization is electronic, not luminal.

Soon afterward experiments with the photoelectric effect revealed three phenomena that were inconsistent with the "classical" theory of light waves and electrons:[13]

1. **Frequency Dependence:** According to classical theory, more intense EM wave-energy of any frequency should produce higher-energy electrons. However, the kinetic energy of the ejected electrons depends only on the light frequency, not on the intensity.
2. **Frequency Cut-off:** According to classical theory, more intense EM wave-energy of any frequency should cause some electrons to be ejected. However, no electrons are ejected when the frequency is below the cut-off frequency, no matter how intense the radiation.
3. **No Time Lag:** According to classical theory, the wave-energy of an emission from a single electron should spread spherically and be uniformly distributed over the wavefront. The receiving electron at some distance should require considerable time to absorb enough energy from the wavefront to be ejected. However, often no such time lag is observed. All the wave-energy from the source emission is absorbed by the receiving electron with only the light time-travel delay.

In sum, the argument for the flying photon was that since the absorption and emission of light by electrons could not be explained by the older, non-quantized "classical" wave and particle models, light had to consist of flying particles. This conclusion did not follow from the facts, and was inconsistent with the overwhelming evidence of the wave nature of light. In fact, many physicists now admit that the photoelectric effect is explicable if light is a spreading wave, but matter is quantized.[14] However, the photoelectric effect is still commonly cited as proving that light is composed of photons. To effectively resolve this problem, we need a comprehensive physical theory of light and electrons and their quantized interactions that is consistent with the working equations and concepts of QED:

1. **Light consists of Waves:** Light can be emitted by individual electrons and positrons as wave-quanta, or it can be produced by non-quantized "classical" mechanisms (e.g. radio waves). No matter how produced, all light consists of waves in a medium.
2. **Electrons are Extended Wave-Structures:** Electrons are not point particles. They are structures composed of circulating EM waves. An electron or positron, bound or free, is

not a particle associated with a field; it *is* its EM field. It is as large as its influence in space. QED's electronic wave-function represents at least some aspects of the physical wave-structure of the electron.

3. **The Electronic Structure is Quantized:** The amplitude and spatial extension of an electron's EM waves are fixed by its structure. Thus a free electron's momentum is determined only by the frequency of its EM waves (de Broglie relation: $\rho_e = hf/c$).
4. **Electrons Incorporate and Expel EM Waves:** The incorporation of additional waves increases the electron's frequency and therefore its total wave-energy. When electrons expel waves into the environment, their frequency is reduced along with their total wave-energy.
5. **Electronic Wave-Energy Exchange is Quantized:** Most physical parameters of the wave-quanta that electrons absorb and emit—length, width, and amplitude—are fixed by the electron's wave-structure. Only the frequency-wavelength is variable and determines the wave-energy of the quantum ($E_{quant} = hf$).
6. **Planck's Constant, h, is an Electron-Structure Constant:** It describes electrons and the quanta they exchange with their environment. It does not describe all freely propagating light. It determines the mass of an electron ($m_e = 2R_\infty h/c \propto^2$), which has nothing to do with freely propagating light.
7. **Quanta are Emitted Directionally:** Upon emission of a quantum, an electron recoils in the opposite direction. Individual electronic emissions therefore do not have and initial spherical symmetry and do not obey the inverse square law.
8. **Quanta Spread in Proportion to Wavelength:** When an electron emits a quantum of light, its EM waves begin to spread in space by Huygens-Fresnel diffraction, as do all freely propagating waves. The higher the frequency, the less the spreading of the wave-packet. At very high frequencies (x- and γ-radiation), the quanta may not appear to spread at all over short distances; i.e. the wave-packet will have a more particle-like character.
9. **Background Radiation:** In any region of space there is significant EM wave-energy of all frequencies from all near and distant sources (man-made, thermal, radioactive, solar, Cosmic, etc.). This radiant energy creates a highly energetic EM background (i.e. quantum fluctuations, the mode, zero-point field) that is undetectable except by its interactions with electrons (in photomultiplied "clicks").
10. **Wave Superpositioning is not Destructive:** The amplitudes of innumerable waves from all sources at all distances superimpose at any given point in space without affecting one another. As there is no actually "destructive" interference, the EM radiation background is more energetic than generally assumed.
11. **Electrons are Coupled to the Background Radiation and other Electrons:** An electron cannot exclude background waves from its structure. Its waves are constantly superpositioning with background waves and the waves of other electrons. This coupling induces both quantum emission and absorptions.
12. **The Absorbed Quantum is the Product of Superpositioning:** The wave energy of the absorbed quantum does not usually come from the known source only, nor from a single emitted quantum, but from the superpositioning of source and background waves of a given frequency upon the receiving electron.

13. **No Independent Knowledge of Emitters:** In any laboratory setup, the origin, number, timing, and spread of emitted quanta are unknown. Statements about emissions are inferences from the detection events.
14. **Statistical Prediction:** Because neither the background radiation, nor the state of the receiving electrons, nor the aforementioned qualities of the emitted quanta can be known, we can make only statistical predictions concerning where and when absorption events will be observed.

These principles are consistent with the known phenomena, and can be further characterized and improved upon by experimentation. They are sufficient to account for the photoelectric effect:

1. **Frequency Dependence and Frequency Cut-off:** The momentum of the ejected electrons and the ability to eject electrons at all depend only on the frequency of the absorbed waves. Apparently, the other physical parameters of the wave-quantum that the electronic structure can absorb—the number of waves and the amplitude—are fixed by the structure of the receiving electron.
2. **No Time Lag:** Electrons emit quanta of light directionally and there is less spatial spreading at higher frequencies. Therefore the inverse-square law does not apply to individual emissions, and a much higher amount of the emitted quantum's energy can arrive at the target electron. In addition, the wave-energy that the electron absorbs does not come from the source alone, but from the superpositioning of source and background waves. In addition, since the electron is as large as its EM influence in space, its reaction cross-section is larger than generally assumed. Finally, the number, location, and timing of quantum emissions from the source is unknown, therefore the absorbed quantum may be the product of the superpositioning of multiple quanta emitted from the source.

These principles are routinely observed in the laboratory. In a report of a low-light experimental setup,[15] photoelectric detectors registered "dark" counts even when the source was not operating (background EM radiation). The "photons" from the source were filtered to the intensity of one-tenth "photon" (not an indivisible particle). This subphotonic EM energy was sufficient, even at a distance of one meter, to produce additional photomultiplier counts (directional emission plus superposition of source waves and background waves.) Experimenters have also given us some idea of the potential physical size of electrons. An electron bound to an isolated hydrogen atom was detected, by its scattering of light, at a distance of several centimeters.[16] Carver Mead asserts that electrons are waves that expand to fit whatever container they are in; it's easy to make an electron that's 10 feet across, and electrons in super-conducting magnets are a mile long.[17] Electrons, protons, and neutrons are not point particles associated with fields or forces; they *are* their extended fields and forces. They are complex structures as large as their electromagnetic, gravitational, and other effects in their surrounding space. They are limited in size only by their interactions with other surrounding "particles".

5. THE COMPTON EFFECT

Historically, the discovery of the Compton Effect convinced most physicists that EM radiation was composed of flying particles. In his experiments, Compton allowed x-radiation of a sharply defined

wavelength to strike a graphite target. He found that the scattered x-radiation at any given angle had intensity peaks at two wavelengths; one of them identical to the incident wavelength, the other being longer by an amount that varied with the angle at which the scattered x-rays were observed: $\Delta\lambda = \lambda' - \lambda = \lambda_C (1 - cos\ \theta)$, where λ_C is the Compton wavelength: $h/m_e c$. As its formula contains Planck's constant and the electron mass, it is evidently related to the electronic structure. The modified x-radiation was scattered by electrons that were freed. Their direction and momentum were consistent with the direction and increased wavelength of the scattered x-radiation. Momentum was conserved, which some interpreted as a billiard-ball-type collision between a photon and an electron. Since the x-ray scattering did not follow the rules of "classical" Thomson or Rayleigh scattering, scientists concluded that x-radiation must be composed of particles. However, consider that:

1. Any physical model, whether of wave absorption/emission or particle collision/rebound, will yield the same calculated results at various angles as vectorial energy-motion must always be conserved.
2. There is no "collision between billiard balls". We now know that both the bound and the freed electrons absorb a quantum of x-radiation and then emit another quantum. See the Feynman diagram:

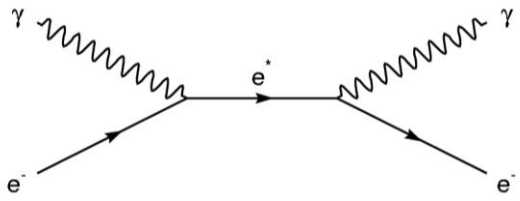

Figure 2. Feynman diagram for Compton Scattering

What is measured is not a slower photon, but a longer wavelength in the directed radiation emitted by recoiling free electrons. The increased wavelength is best explained as a Doppler shift in the radiation caused by the electron's recoil. This was indeed Compton's original interpretation.[18]

3. The scattered x-radiation is detected by a photoelectric detector, and the photoelectric effect does not require the flying-photon theory.

6. ANTICORRELATION AND OTHER "PHOTON" EXPERIMENTS

Realizing that the photoelectric and Compton effects can be explained with wave theory as long as matter's interaction with light is quantized, scientists have sought other ways to prove that light itself is quantized—that it is composed of flying photon particles that do not spread in space. In their experiments, they compare a "classical" prediction with photonic prediction. If the photonic prediction is validated, they conclude that the flying photon exists. Ignoring the counsel of Feynman and others, they assume that their source produces a single photon that strikes a beam splitter and is either transmitted or reflected, producing a photoelectric count in either R or T but not both. (See Figure 3.) They argue that if light were a wave, it should be split equally at the beam splitter and there should be either coincident counts at R and T, or no counts at either detector.

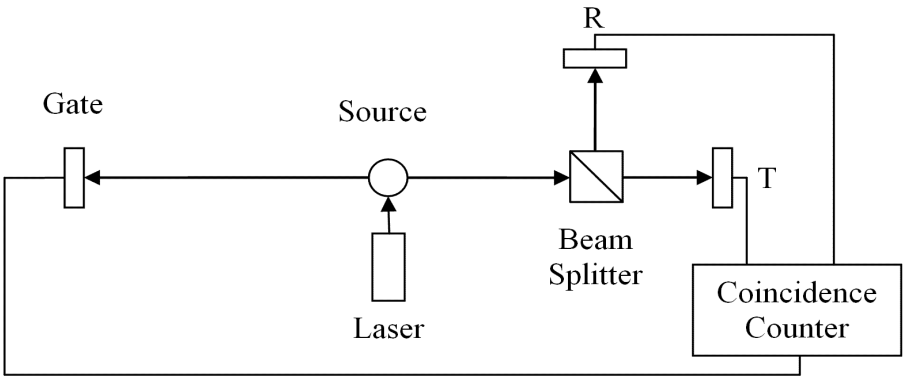

Figure 3. Anti-correlation experimental design (redrawn from Thorn, 2004)

In published anticorrelation experiments,[19,20,21] laser light is pumped into a macroscopic material. This material is presumed to produce one pair of photons at a time that fly in opposite directions into photoelectric detectors and produce clicks. The photons supposedly pass through lenses, filters, and beam splitters unaltered. When one of the supposed photons causes a photoelectronic "click" in the gate detector, the device becomes sensitive for a short time to photoelectric clicks in the detectors after a beam splitter, in R and T as shown in Figure 3. Any nearly simultaneous detection in the Gate and either R or T is presumed to be the other photon of a correlated pair. The experiment is performed at low light intensities so as to minimize the number of time-correlated detections in the R and T detectors. As some authors stated; "In this case, quantum mechanics predicts a perfect anticorrelation for photo-detections on both sides of the beam splitter (a single-photon can only be detected once!), while any description involving classical fields would predict some amount of coincidences."[22] This prediction is expressed by the degree of second-order coherence: $g^{(2)}(0) = N_{GTR}N_G/N_{GT}N_{GR}$, where N_G is the number of singles counts at the Gate, and N_{GTR} the number of threefold coincidences. The "classical" inequality tested is $g^{(2)}(0) \geq 1$. The experiments show that $g^{(2)}(0) \ll 1$.[23]

The experiments reveal that when there is a Gate detection, there is a much higher probability of a detection at either R or T than at both R and T. Sufficient light arrives at either R or T with much greater frequency than at both R and T. Does this prove that light is made of particles that go this way or that way at a beam splitter? Consider the problems with their arguments and their conclusions:

1. **Argument from Ignorance:** The experimenters' primary argument for the photon, like Feynman's argument, is an argument from ignorance: "Since we can't understand how light waves could produce this single effect, light must be made of flying particles." This is a weak argument, and ignores the requirement for the wave-model of light to explain all other phenomena. It also ignores the fact that QED models waves, not flying particles. Let us try to explain the effect according to the QED-compatible theory of light and electrons presented here.
2. **Low Intensity Experiments Deviate from Classical Predictions:** Classical wave-propagation and reflection principles apply only to high-intensity light experiments where there are enormous number of quantized emissions and absorptions. In low-intensity experiments, the effects of the quantized electronic production of light; the directional

emission of wave-quanta, the absorption and re-emission of waves by electrons in the air molecules, beam splitters, and photomultipliers; and the background radiation will all be more pronounced. At low intensities, the light wave amplitudes that exist at any point come from fewer quantized absorption/emission events. The "graininess" due to the quantum absorption/emission process becomes prominent. Since electron-absorbed light is re-emitted directionally, low-intensity results with fewer emissions will differ from the "classical" spherical-spread predictions. This indeterminacy is what necessitates the statistical treatment given by QED. Theoretically, at very low intensities, a 50/50 beam splitter has a probability of emitting light amplitudes only in one direction—say from a single quantum absorption/re-emission in the beam splitter, or from several emissions that happen to occur in the same direction. Light could be split 0/100. Only at higher light intensities are there so many quantum absorptions and emissions that the results will approach the predictions of classical wave theory.

3. **The Importance of Background Radiation:** In all quantum experiments, there are large numbers of "dark counts" (~250cps in Thorn et al.). This means that the background radiation is sufficient to produce quantum absorptions. Photoelectric detections require no input from the source at all! Therefore, the source need only supply a minimal amount of additional amplitude to produce additional, time-correlated detections. A detection certainly does not require that the entire wave-energy of a quantum emitted in the source arrive intact and be absorbed by a single electron to produce an additional "click".
4. **QED is a Wave Model:** In every such experiment, the outcome is that the QED prediction is correct and the "classical" or "semi-classical" prediction wrong. As shown above, QED is a wave model of light propagation and interference and contains no flying light particle. Only the detection is a particulate event. What the experiments show is that QED's wave model is superior to the classical or semi-classical model. They do not prove that light consists of flying particles.
5. **The QED-based Wave-Interpretation of Anti-Correlation Experiments:** As per Feynman's model, when light is emitted simultaneously in both directions from the source, light amplitudes spread in space ("light goes everywhere", "by shrinks and turns"). The amplitudes arriving at the Gate and beam splitter will be reduced by the distance traveled and by scattering by air molecules (if not in a vacuum). In the beam splitter much more scattering occurs as light is absorbed and re-emitted in all directions by bound electrons throughout the substance of the splitter. Detections at G, R and T are the result of amplitudes from all possible paths summing at the detector. When the Gate receives just enough additional amplitude to produce additional counts, R and T receive less than 50% of that amplitude. Therefore it is understandable that GRT coincidences should be very unlikely at sufficiently low intensities. In such situations there will be more GR and GT coincidences than GRT coincidences as the former can be produced by deviations from 50-50 splitting in the beam splitter and by variations in the background radiation. The QED-compatible wave-theory of light and electrons presented here is sufficient to explain the result.
6. **Imaginary Photons:** The flying particle interpretation is not only inconsistent with QED, but also ignores the insurmountable defects of the particle theory of light as seen in Table 1 above. It also presumes the impossible—to "know" that a photon is created here, travels through space from A to B, goes this way or that way in a beam splitter, is "collimated"

by a lens, etc. All that can be known is the experimental set up and resultant detection events. Every statement about photons is an unjustifiable inference from the phenomenon. Indeed, the experimenters' supposition that only one or two quanta are being emitted at any given time by their source is highly improbable. They direct high intensity laser light onto ~10^{22} atoms in the source, producing unknown numbers of quantum absorptions and re-emissions in all directions. Given the amplitude attenuation and scattering effects, it is probable that many nearly simultaneous quantum emissions in both directions from the source are required to produce sufficient additional amplitude at the detectors to produce additional photomultiplier counts at R or T during the Gate window.

7. **Miraculous Photons:** In various anti-correlation experiments the supposed flying photons are "focused" by lenses, "selected" by polarizing filters, and "guided" by beam splitters, light tubes, fiber optic cables, etc. There is no possible physical explanation for how a single particle of light could be "directed" either straight through, or reflected at 90 degrees by the atoms in a beam splitter. The very idea that a particle of light can even pass through several millimeters of glass (10^{22} atoms/cm^3) or any other solid material (solid with electrons that is) and emerge unchanged is not only nonsensical, but contradicts the treatment of light-matter interactions in QED, where light amplitudes are scattered in all directions by electrons throughout the glass. It is perhaps because the full QED wave-analysis of any particular experiment is so extremely complex and laborious (adding up amplitudes for all possible light paths and absorption/re-emission events), that experimentalists resort instead to the simple "flying photon" idea. (For further discussion of these and other theoretical and technical problems with anticorrelation experiments see Sulcs, 2003.[24])

The particle theory of light is falsified by the known evidence, so no experiment can ever prove that light is a flying particle. Interpreting any experiment according to the particle hypothesis produces nonsense. The phenomena are explicable without paradoxes if we assume instead that light is a wave in space. The emission and absorption of light by electrons is quantized, and that once emitted, the quantum behaves as a spreading packet of waves (superpositioning, diffraction, etc.). It is long past time to expunge the photon from the scientific lexicon.

7. ELECTRONS ARE WAVE-STRUCTURES

The photonic model of light is but one source of the unreality of "quantum phenomena", the other is the particle model of electrons. This is another instance in which "classical" concepts interfere with our ability to understand the microcosm. Electrons are thought of as tiny particles associated with a larger EM field. However the experimental evidence indicates electrons are extended EM wave-structures. They *are* their EM fields; they are as big as their EM fields. The evidence indicates that electrons are composed only of circulating EM radiation: high-frequency light can produce electron-positron pairs and the annihilation of an electron-positron pair at low velocities produces only light. Electrons do not participate in the weak or strong nuclear "forces". The presence of spin ($h/2\pi$) and electromagnetic moment indicate that the EM wave-energy propagates around an axis; that there is an axial symmetry to the propagation of the electron's waves. Double slit experiments with single electrons clearly demonstrate their wave-nature. The EM waves of a single electron can pass through both slits, producing self-interference that determines the subsequent path of the electron. This results

in the slowly accumulating interference pattern in the detector. This self-interference is not unique to electrons; it also has been documented with standing wave-structures in a fluid. Passing circular wave-structures through a double slit one-at-a-time produced the typical wave-interference pattern seen with light waves and with electrons.[25] Again, we must abandon careless, ambiguous terms like "wave-particle duality" and replace them with a working theory of the physical phenomena in question.

The association of electrons with nucleons forms atoms. The electronic wave-structure somehow opens up and surrounds the nucleus, creating a new composite nuclear-electronic entity that is stable. The electron's waves take on configurations around the nucleus that we describe as orbital shells. The orbital is that configuration of the electron's waves that is stable at that distance from the nucleus, and in the presence of the other electrons. When an electron bound to an atom absorbs waves it expands to become a larger shell—a larger wave-structure surrounding the nucleus. When it emits waves, it shrinks in size and "falls into a lower shell". An atom-bound electron can absorb enough waves to expand to the point that it escapes the attraction of its nucleus.

8. CONCLUSION

The particle-photon theory of light is incompatible with known wave-qualities of light; is not necessary to explain the photoelectric, Compton, or anti-correlation effects; and produces contradictions (paradoxes). Our successful descriptive model, QED, neither contains, predicts, nor supports the particle theory of light. Electronic and positronic wave-structures, whether alone or incorporated into other "particles" are the source of quantization and therefore of quantum mechanical effects. If we admit that EM radiation of all wavelengths is composed of waves freely propagating in a medium and that electrons are EM wave-structures, we can eliminate the paradoxes of Quantum Mechanics and the schism between classical and quantum electrodynamics. Radio waves and x-rays are both waves; they differ only in their wavelengths, their degrees of spatial spreading and diffraction, the ways in which they are generated, and the ways in which they interact with matter. Without the photon, we can form a unified theory of light and its interactions with matter; a unified electrodynamics. Nature makes sense when our theories conform to the facts.

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