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

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Abstract

Quantum Electrodynamics (QED) is not a theory of physical causation but only a probabilistic prediction model that has been modified as needed to correspond to observations. Contrary to popular belief, QED does not model light as flying photons, but instead as wave-like probability amplitudes spreading in all directions from the source—by shrinks and turns. Where the amplitudes superpose constructively is where light-detection events are more probable. QED's model supports the theory presented here: that light is a wave and electrons are wave-structures that absorb and emit light waves in discrete wave-packets (e-quants). E-quants are emitted directionally and then begin to spread in space and superpose with ambient radiation as do all free waves. An e-quant absorption is produced by the complex superpositioning, upon an electron, of all source and background waves. The e-quant detected is rarely, if ever, the e-quant emitted. This wave theory of light and electrons encompasses the known phenomena, including classical electrodynamics, the photoelectric effect, the Compton Effect, and the anticorrelation and other quantum experiments.

Keywords: anti-correlation, Compton Effect, electron, light, photoelectric effect, photon, Planck's constant, quantum, Quantum Electrodynamics, waves

1. QUANTUM ELECTRODYNAMICS IS A WAVE-MODEL OF LIGHT

It is commonly assumed that the success of Quantum Electrodynamics (QED) proves that light is made of particles. This is an error, a myth; for both light and electrons always behave as waves,(1) and the particle theory of light is inconsistent with most known qualities of light. Therefore we should expect that all interpretations of quantum experiments involving particles (photons) traveling by this or that route to a detector will produce nonsense—the quantum paradoxes. How can we resolve this confusion about the nature of light? Fortunately, Richard Feynman has provided an unambiguous description of QED's concepts and approach in his book of that title.(2) His version of QED (Dirac-Feynman) is also known as the path-integral or sums-over-histories approach. It is acknowledged to be equivalent to the Heisenberg and Schrödinger formalisms. Using QED's own concepts, I will propose a wave theory of light and electrons and their quantized interactions that can explain all known quantum phenomena.

In his book, Feynman presents QED as an empirical statistical model for predicting quantized light-matter interactions. It is not a theory of the nature of light; it contains no physical hypotheses or explanations, but only probability-prediction concepts. He describes how QED has been modified *ad hoc* over many decades in order to incorporate and predict the observed facts. Feynman explains that in QED light sources produce not physical particles or waves, but wave-like "probability amplitudes" that propagate at *c* in space (not superluminally). The amplitudes spread in all directions and superpose (interfere) just as real light waves do according to the Huygens-Fresnel principle: by spherical wavelets from every portion of the wave front. Feynman restates this principle as light "has a nearly equal chance of going on *any* path".(3) As they propagate in space, the probability amplitudes shrink according to the inverse square law and rotate in space according to their frequency ("shrinks and turns"). Adding up all the resultant arrows for all the possible paths light may travel to the receiver renders a final amplitude arrow (Figure 1.). Squaring this arrow yields the probability that a detectable light-matter interaction will be observed. Where the probability amplitudes superpose constructively is where events (e.g. photomultiplier counts) are more likely to occur; where they superpose destructively is where events are less likely to occur.(4)

QED's method is, I submit, just wave-mechanics converted into a probability calculus. The square of any wave's amplitude is its intensity ($A^2 = I$); and a greater intensity at a given point and time would naturally produce a higher probability of an observable light-matter interaction.

Feynman’s “shrinks and turns” are normal wave phenomena—amplitude attenuation and phase change with distance. Contrary to an oft-stated opinion, the fact that these arrows are complex numbers does not imply that cannot represent real, physical waves. Complex numbers are used to represent physical parameters in many science and engineering applications.

Feynman admits that the wave theory of light can account for all the phenomena modeled by QED when the light is intense; but insists that “wave theory cannot explain how the (photomultiplier) detector makes equally loud clicks as the light gets dimmer.”(5) On this basis alone he rejects wave theory and concludes that “light is made of particles.”(6) His conclusion does not follow from the facts. It is an argument from ignorance; an admission that he does not know, or want to know, how to explain the photoelectric effect using wave theory. I will propose such a theory below.

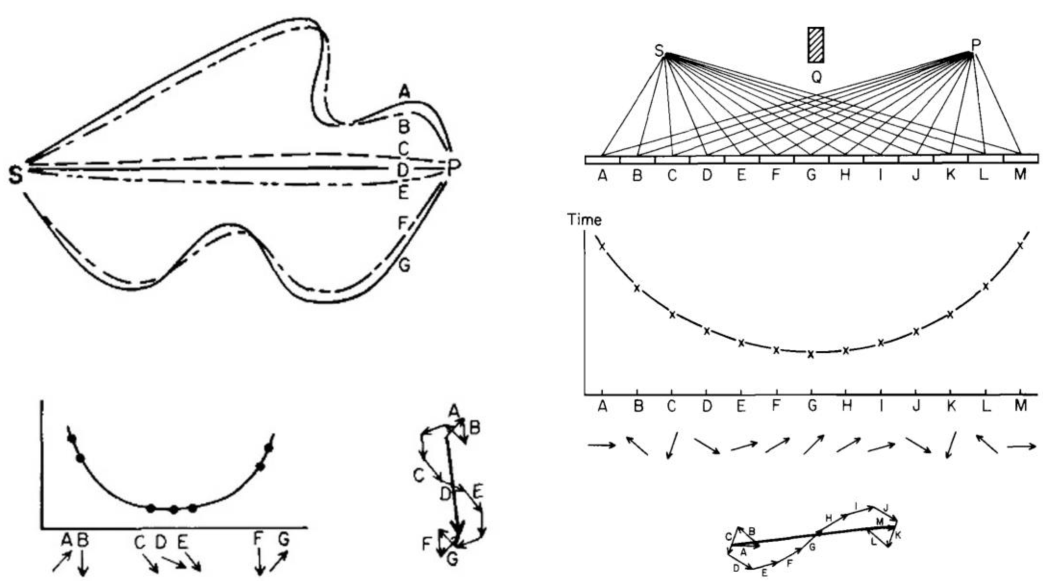

Figure 1. Feynman’s QED provides insights into light waves and their interactions with matter. It explains why light appears to travel in straight lines and to reflect off the center of a glass pane; when it is actually spreading everywhere and being absorbed and re-emitted by all atoms in the pane. Only near the straight line (least time) path do the resultant arrows point in nearly the same direction and superpose constructively. (reprinted by permission from Princeton University Press)

Even as Feynman asserts that light consists of particles, he admits that QED does not model the motion of any flying light particles. He knows that QED states only that a photon of light emitted by the source 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.[(7)] He realizes that it is absurd to ask "which way the photon goes", yet he often finds himself thinking in those terms. He says that all the photonic paradoxes disappear if one stops thinking about light as particles flying between source and receiver and instead just performs the probability calculations. In spite of this knowledge, he continues to speak of photons as if they are real "particles of light". Feynman was confused, and his confusion persists to this day. In a recent review article on the photon, the authors also claim that light is composed of particles flying through space, but then admit that QED only predicts the probability of detection events and that the particle theory of light cannot be taken 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 to which a 'click in the detector' refers."[(8)]

Realizing that the flying photon makes no sense as a physical theory, Feynman concludes that Nature is absurd,[(9)] and this is why physics has given up on trying to find physical models to explain the phenomena.[(10)] I submit to you that it is far more likely that it is Feynman's approach to physics that is absurd, not Nature. He is using an outdated epistemology. I have previously exposed the origin of both Relativity and Quantum Mechanics in Bishop Berkeley's subjective idealism, as interpreted and applied by David Hume, Ernst Mach, and Albert Einstein.[(11)] Like them, Feynman artificially limits physics to describing and predicting the observer's experiences and measurements, as if the physical Cosmos and the causes of things do not exist or cannot be known. He asserts, echoing Ernst Mach, that the only criterion of a good "theory" is whether its predictions agree with experimental observations. This observer-based program is anti-philosophical—it does not attempt to make sense of the physical world. To do so requires a theory of what exists and causes our experiences. Feynman did not produce a working physical theory light emission, propagation, and absorption because he did not believe physics required such a theory. His confusion extended to the nature of his own epistemology; as he claimed that QED is a description of "what Nature is really doing underneath nearly all the phenomena we see in the world".[(12)] Feynman was lost in the contradiction between his observer-based prediction model and his natural common-sense realism.

2. BEYOND QED: THE WAVE AND PARTICLE THEORIES OF LIGHT

If we choose instead to try to understand the world as a physical system, we need an entirely different approach to physics. We need to use our minds to reach beyond our consciousness, beyond our experiences and measurements, to create theories about what exists and produces the phenomena that we observe. This effort has traditionally been called "natural philosophy". In this case, in order to understand the physical nature of light, we must logically weigh the evidence for and against the two candidate theories:

Particle Theory: Light is a discrete particle flying through a void.

Wave Theory: Light is a spreading wave in the electromagnetic medium of space.

These theories are logically and physically incompatible; they imply starkly different properties. Which is the better theory? Table 1. illustrates the fact that *the particle theory of light is contradicted by all known facts concerning light and light-matter interactions.* To start with, only waves can have frequency, amplitude, polarization, superpositioning, invariant velocity, etc. A particle is, by definition, a localized, unchanging microscopic entity; it cannot have any wave-qualities. It cannot have any relationship with radio waves that are hundreds of meters long. It cannot be composed of alternating electrical and magnetic fields as light waves are. A particle's velocity in a void—a space with no physical qualities—should vary with the velocity of its source and its "energy"; it cannot be fixed relative to any frame. Particles cannot superposition as waves do; two particles at the same location must stick together, collide and rebound, or mutually annihilate. Particles also cannot be filtered to arbitrarily small amplitudes as waves can. A single particle cannot spread, pass through two slits simultaneously and create an interference pattern. The double slit experiments and all other low-intensity quantum light experiments contradict the particle theory and support the wave theory of light and electrons presented here. As shown above, QED works because it models light as spreading waves, not as flying particles.

The contradictions between the particle theory and the wave-nature of light are presumed to be resolved by the notion of wave-particle "duality". This is only a euphemistic re-statement of a contradiction. Wave-particle duality thus violates the first rule of natural philosophy: non-contradiction. Imagine the consequences of our accepting all contradictions as "dualities". We would have true-false duality, up-down duality, good-bad duality, dead-alive duality, etc. The tolerance of contradictions destroys cognitive functioning. Philosophy requires us to identify contradictions and resolve them with a better theory.

Table 1. Wave vs. Particle Theories of Light

Explains or can accommodate:	Wave Theory	Particle Theory
Wavelength and frequency	Yes	No
Invariant velocity independent of source velocity	Yes	No
Superpositioning-interference	Yes	No
Huyghens-Fresnel diffraction, refraction, etc.	Yes	No
Continuous spectrum (including radio waves)	Yes	No
Light of "subphotonic" amplitudes	Yes	No
Laser	Yes†	No†
Blackbody spectrum	Yes†	No†
Photoelectric effect	Yes†	No†
Compton effect	Yes†	No†
Anti-correlation experiments	Yes†	No†
Quantum Electrodynamics' computational method	Yes†	No†

†Requires that electrons absorb and emit light as wave-quanta as described by this theory

The almost universal belief in the demonstrably false particle theory of light is understandable. The actual nature and method of QED is not taught to physicists at the undergraduate level, but only to post-graduate students specializing in QED. Only specialists realize that it is just an observation-prediction model that gives us no idea of what, if anything, objective reality actually is.[(13)] Feynman tells us why this is the case: the full QED computation of the simplest experimental situation is so incredibly complex that it takes graduate students four years to learn how to master it. They must learn to add up all the little arrows for all possible paths, accounting for the spherical spreading of light from every portion of the wavefront. They must account for the superpositioning of light amplitude arrows traveling from all atoms in the source to all electrons in the photomultiplier by all possible paths—including their amplitude attenuation, polarization, frequency, and phase. They also must account for quantized light absorption and re-emission in all directions by every atom in all matter in the vicinity of the experiment. For any real problem, the computation involves billions of "little arrows"; in fact one can never account for all amplitudes from all sources including the background radiation. So all other physicists are taught the much simpler myth—that light is made of flying particles. In their "photon" experiments, scientists cannot and do not apply the full QED treatment; but instead work with simplifications and approximations. They design and interpret experiments based on the false photon theory of light—thereby producing all the contradictions and unreality of "quantum reality".

One way of avoiding some of the deficiencies of the particle theory is to theorize that light is composed of “wave-packets”. This is a modified wave-theory, not a particle theory. I will argue below that the wave-packet concept is indeed a part of the solution. Electrons do emit and absorb light as “wave packets”. The crucial question is what happens to the wave-packets once they are emitted. Do they remain as discrete wave-packets, of microscopic dimensions, or do they begin to spread in space by diffraction and superpose with ambient waves as do all waves?

3. A WAVE THEORY OF THE PHOTOELECTRIC EFFECT

Since Feynman admitted that wave theory can explain everything described by QED except the photoelectric effect, we need to produce a wave theory of light and electrons that explains the photoelectric effect, and thereby explain all quantum phenomena. We need to interpret QED’s accurate wave-function descriptions of light and electrons as representing, in some way, true physical waves in electromagnetic (EM) space. We can then unify classical and quantum electrodynamics by superseding both with a better theory.

Let us begin with a typical textbook argument against wave theory. Three phenomena seen in the photoelectric effect are presented as being inconsistent with the classical theories of light waves and electron particles:[14]

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, no such time lag is observed. All the wave-energy from the source emission appears to be absorbed by the receiving electron with only the light time-travel delay.

In sum, the argument for the flying photon is that since the absorption and emission of light by electrons cannot be explained by the old “classical” theories of light and matter and their interactions, light must consist of flying particles. This conclusion does not follow from the facts. The old theory was produced to explain qualitatively different, macroscopic light-matter interactions. Only in the past century have we learned about electronic light absorption and emission. We need to modify and expand our previous concepts and theories in order to incorporate the new knowledge. In this direction, some physicists have asserted that the photoelectric effect is explicable if light is a classical spreading wave but matter is quantized.(15) This is known as the "semi-classical" theory. Others have claimed that photon anti-correlation experiments provide the final "proof" that light is made of particles. To dispel this confusion and begin to understand Nature, we need a new and better theory of light, electrons and their interactions that is consistent with both classical electrodynamics and QED. It must provide a satisfactory physical explanation for the photoelectric effect, the Compton Effect, the particle-like behavior of x-rays and gamma rays, and the anticorrelation experiments:

1. **Light is a Wave in Space:** No matter how produced, how complex, or how different from other waves, light consists of waves. These waves can be produced by various mechanisms including non-quantized "classical" emission (e.g. thermal, radio, etc.), and quantized emission from the interior of electrons (and positrons).
2. **Electrons are Extended Wave-Structures:** Electrons are not point particles. They are complex structures composed of circulating EM waves. An electron, bound or free, is not a particle associated with a field; it *is* its EM field. It is as large as its entire influence in space. Schrödinger's electronic wave-function represents at least some aspects of the extended wave-structure of the electron.
3. **The Electronic Wave-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. **Planck's Constant, h, is an Electron-Structure Constant:** It describes electrons and the electronic wave-quanta they exchange with their environment. It does not describe freely propagating light. Notice that h also determines the rest mass of an electron ($m_e = 2R_\infty h/c \propto^2$) which has nothing to do with freely propagating light.
5. **Electrons Can 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 from their structure into their environment, their frequency is reduced along with their total wave-energy (total motion).

6. **Electronic Wave-Energy Exchange is Quantized:** Most of the 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 electronic light-quantum ($E_{quant} = hf$).
7. **Quanta are Emitted Directionally:** An electronic wave-quantum ("e-quant") is emitted directionally. (Figure 2.) Upon emission, the electron recoils in the opposite direction. Individual e-quant emissions therefore do not have initial spherical symmetry and do not obey the inverse square law. This contrasts with the classical model of spherical spread from any source.

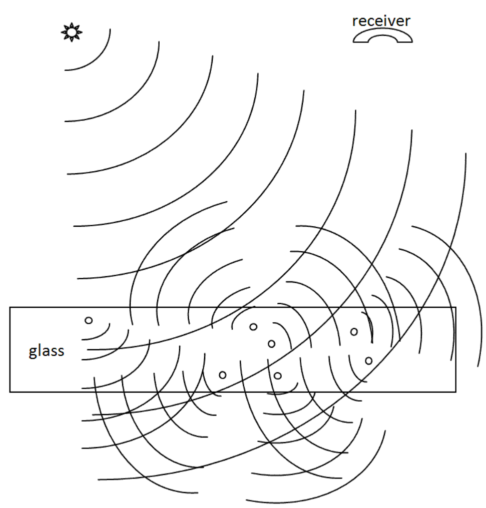

Figure 2. Source wave-amplitudes are absorbed and then re-emitted in random directions by electrons within the glass, beam splitter, crystal, etc.

8. **E-quants Spread in Space in Proportion to Wavelength:** Once emitted in some direction, an e-quant's waves begin to spread in space by Huygens-Fresnel diffraction. The higher the frequency, the less the spreading of the emitted wave-packet. At very high frequencies (x- and γ-radiation), e-quants may not spread significantly over short distances; they are more particle-like in this respect.
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 detectable only by its interactions with electrons ("dark counts").

10. **Wave Superpositioning is not Destructive:** The amplitudes of innumerable waves from all sources at all distances superpose at any given point in space without affecting one another. As there is no "destructive" interference, the EM radiation background is much more energetic than generally assumed.[16]
11. **Electrons are Coupled to the Background Radiation and to other Electrons:** An electron cannot exclude background waves from its structure. Its waves are constantly superpositioning with ambient light waves and the waves of nearby electrons. This coupling plays a role in inducing e-quant emissions/absorptions, and in other phenomena.
12. **An Absorbed E-quant is the Product of Superpositioning:** The wave energy of an absorbed e-quant does not usually come from a single spread-out e-quant emitted by the source, nor even from several source e-quants, but from the superpositioning of source and background waves of a given frequency upon the electron. The e-quant waves that are absorbed by an electron are rarely, if ever, just the waves of a single e-quant that was emitted by the source. It is impossible to produce a radiation-free space in the lab.
13. **No Independent Knowledge of Emitters:** In any laboratory setup, the origin, number, timing, and spread of emitted e-quants are unknowable. All statements about emissions are nothing but inferences from detection events. For instance, a single absorption event (photomultiplier count) at a distance most likely results from the superpositioning of waves from many attenuated source e-quants with the abundant background radiation.
14. **The Statistical Method is Required due to our Ignorance:** Because we cannot now know, and will never be able to know, the number or direction of the emitted e-quants, their spread, the number and location of all absorption/re-emission events, the state of the background radiation, the state of the receiving electrons, etc., *we will always be limited to making statistical predictions* concerning where and when absorption events will be observed.

The above principles are consistent with the known phenomena, and can be further characterized and improved upon by experimentation. They are sufficient to explain 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 because all other physical parameters of the e-quants—e.g. the number of waves and the waves' amplitude—are fixed by the structure of the electron (as described by Planck's constant).
2. **No Time Lag:** Electrons emit e-quants directionally and there is less diffractive spatial spread at higher frequencies. Therefore the inverse-square law does not apply to individual e-quant emissions, a much higher amount of an individual emitted e-quant's energy can arrive at the target electron. In addition, the wave-energy that the receiving electron absorbs does not usually come from source e-quant waves alone but also from background radiation. Also, since the electron is as large as its EM influence in space, its reaction cross-section is much larger than generally assumed; it can absorb wave-amplitudes from a larger volume. Finally, since we cannot know how many source e-quants were emitted, the absorbed e-quant is almost always the product of the superpositioning of waves from many attenuated source e-quants with background waves. Therefore no time lag is necessary.

These principles are routinely observed in laboratories. In low-light experimental setups, photoelectric detectors register very large numbers of "dark counts" even when the source is not operating (intense background EM radiation). The "photons" from the source can be filtered to an intensity that is a small fraction of a "photon" (not an indivisible particle), and this subphotonic EM wave-energy is sufficient, even at a distance of one meter, to produce additional photomultiplier counts[(17)] (superpositioning of source and background waves). Experimenters have also given us some idea of the 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.[(18)] A prominent experimentalist and theorist has asserted 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.[(19)] We should no longer hold the out-dated view that electrons, protons, and neutrons are point particles associated with fields or forces; they *are* their extended fields and forces. They are complex, energetic 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".

4. ELECTRONIC WAVE-STRUCTURE AND SELF-INTERFERENCE

It is often argued that since single electrons and other “particles” can produce an interference patterns in double-slit experiments, light can be made of “particles” too. On the contrary, these phenomena demonstrate that electrons and other subatomic particles are EM wave-structures. I believe that Schrödinger was right in his insistence that QED’s electronic wave-function represented real waves. The evidence indeed indicates that electrons are spherically-symmetrical wave-structures composed of circulating EM radiation. They do not “participate” in the weak or strong nuclear “forces”. High-frequency light alone can produce electron-positron pairs and the annihilation of electron-positron pairs at low velocities produces only light. The presence of spin ($h/2\pi$) and electromagnetic moment indicate that the EM wave-energy propagates around an axis; that there is spin, an axial symmetry to the propagation of the electron’s waves.

Just as QED’s electronic wave-function passes through both slits and self-interferes, so the EM waves that make up a single electron pass through both slits and self-interfere, altering the electron’s trajectory. Each additional electron passing through the slits has a different initial trajectory, and therefore a different self-interference pattern and final trajectory. The possible trajectories produce the interference pattern on a screen. This is not improbable; in fact the self-interference of individual wave-structures has been demonstrated with macroscopic circular standing waves in a fluid. When experimenters allowed these wave-structures to pass through a double slit screen one-at-a-time, the self-interference of their waves altered their trajectories so as to build up a typical interference pattern at the target.[20]

An electron is indeed a “smeared-out” wave-structure. As with light, it appears to be a localized point particle due to our particulate detection methods. The wave-nature of electrons and other “particles” is the origin of the “uncertainty principle”. In atoms, it appears that the electronic wave-structures somehow propagate in fixed patterns (orbitals) about the nucleus, and are able to absorb and emit e-quants when bound in this way. Upon absorbing an e-quant, the bound electron has more waves and thus more energy and becomes a higher “shell”. Alternatively, a bound electron can absorb sufficient additional wave-energy that it cannot form a higher shell but escapes completely from the influence of the nucleus (a freed electron).

5. A WAVE INTERPRETATION OF THE COMPTON EFFECT

Historically, the Compton Effect convinced most physicists that EM radiation was composed of flying particles, so we must also re-interpret this phenomenon. 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: $h/m_e c$. The unmodified x-radiation was scattered by electrons that remained bound to the nucleus. The modified x-radiation was scattered by freed electrons. The freed electrons' direction and momentum were consistent with the direction and increased wavelength of the scattered x-radiation. This conservation of momentum was interpreted as implying a billiard-ball-type collision between a light particle and an electron. As with the photoelectric effect, the same fallacious argument was accepted: since x-ray scattering did not follow classical Thomson or Rayleigh scattering rules, x-radiation must be composed of particles. However, consider that:

1. The Compton wavelength, $h/m_e c$, is defined by Planck's constant and the electron's mass, therefore it describes the electronic wave-structure, not light itself.
2. Any physical model, whether of wave absorption/emission or particle collision/rebound, must yield the same calculated results at various angles as vectorial energy-motion must be conserved in any physical system.
3. This is no "collision between billiard balls". We now know that both the bound and the freed electrons absorb an e-quant of x-radiation and then emit another e-quant. This is represented in the Feynman diagram for Compton scattering:

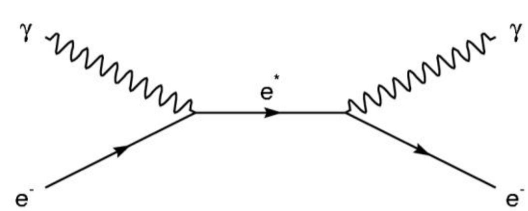

Figure 3. Feynman diagram for Compton scattering

4. What is actually detected is radiation of a longer wavelength, emitted in a given direction by the recoiling free electrons. The increased wavelength is best explained as a simple Doppler shift caused by the freed electron's recoil velocity. This was actually Compton's original interpretation.(21)

5. The scattered x-radiation is detected by a photoelectric detector, and the photoelectric effect does not require the flying-photon theory (as explained above).
6. Because of their high frequency, emitted x-ray e-quants may spread very little over the short distances in such an experiment. So it's possible that the e-quant absorbed in a photomultiplier was nearly identical to an emitted e-quant. However, even an x-e-quant detection could be the product of the superpositioning of several e-quants emitted nearly simultaneously by electrons recoiling in a similar direction. Background radiation would also play a role. Again, we only "know" the detection events; any statements about emission events are just inferences based upon some theory.

6. A WAVE INTERPRETATION OF ANTICORRELATION AND OTHER "PHOTON" EXPERIMENTS

Realizing that the photoelectric and Compton effects can be explained by the wave theory of light as long as light's interaction with matter is quantized, physicists have sought other ways to "prove" that light itself is quantized—that it is composed of microscopic flying particles that do not spread in space.(22,23,24) As I've shown above, if they understood QED's epistemology and method, they would they would not pursue the particle theory of light. They have constructed anticorrelation experiments, where they compare, once again, a classical prediction with a QED prediction. If the QED prediction is validated, they conclude light is composed of flying photons. Like Feynman's argument for the photon, their argument is fallacious—a non-sequitur—it does not follow from the facts. Let us analyze their experiments to see if the QED-based wave theory presented here can explain their findings.

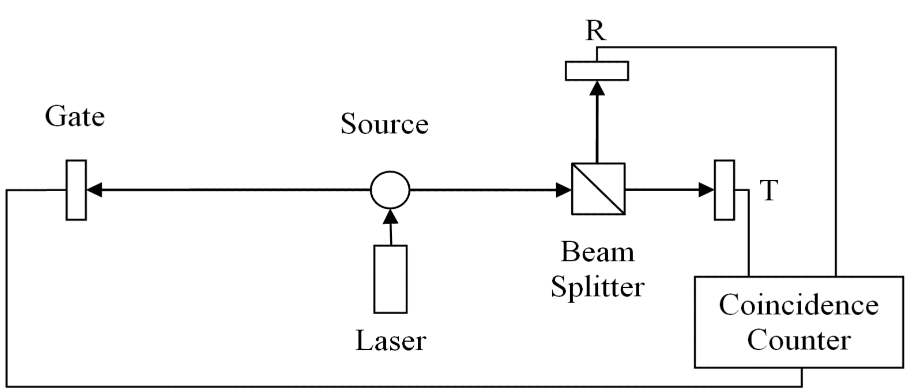

Figure 4. A simple anti-correlation experimental design

In a typical experimental set up, laser light is pumped into a macroscopic source material that is presumed to produce one pair of photons at a time, and these correlated photons are presumed to fly in opposite directions into photoelectric detectors and produce simultaneous clicks in each. When a photoelectric“click” occurs in the Gate detector, the device becomes sensitive for a short time (the Gate window) to photoelectric clicks in the detectors after the beam splitter (R and T). Any nearly simultaneous detections during the Gate window in R or T are presumed to be caused by a correlated photon pair. The experiment is performed at a sufficiently low light intensity so as to minimize the number of time-correlated detections in the R and T detectors and achieve the non-classical result.

We see that, just as with the photoelectric effect, the experimenters use classical theory as their foil. They argue that, classically, light waves spreading spherically from the source should be split equally at the beam splitter, always sending equal amplitude towards R and T. So during the Gate window, there should be either coincident counts at both R and T, or no counts at R or T. They claim that if, during the Gate window, they see counts occurring at either R or T more often than at both or neither, then light must consist of photons that have gone this or that way in the beam splitter. The authors state, “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.”(25) This statistical prediction is typically 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 only (no R or T), and N_{GTR} the number of threefold coincidences. The classical inequality is $g^{(2)}(0) \geq 1$. By carefully adjusting a number of experimental design elements and parameters, they are able to produce $g^{(2)}(0) \ll 1$. In other words, during a Gate window, they can produce a much higher probability of a detection at either R or T than at both R and T or neither R or T.(26) Does this result prove that light is made of particles that go this way or that way at a beam splitter? Not at all. Consider the following:

1. **Argument from Ignorance:** The experimenters’ primary argument for the photon, like Feynman’s argument, is: “Since I/we can’t understand how light waves interacting with matter could produce this effect, light must be made of flying particles.”

2. **Dropping the Context:** The experimenters' argument for the photon, like Feynman's, ignores the fact that the wave theory of light is required to explain all other known phenomena. (Table 1.)
3. **Misinterpretation of QED:** In such experiments, the outcome is that the QED prediction is correct and the classical or semi-classical prediction wrong; but as I have demonstrated, the success of QED's wave-probability model supports the wave theory of light, not the particle theory. The experimenters make the mistake of thinking that QED is a physical theory about flying light particles. It is not. Their claim that a single photon goes this way or that way exposes their misunderstanding of QED.
4. **Low-Intensity Quantized Phenomena Must Deviate from Classical Predictions:** Classical wave-propagation, beam splitting, and reflection principles apply only to the phenomena for which they were invented: non-quantized light-matter interactions (e.g. thermal, radio, etc.) and high-intensity quantized phenomena with very many electronic absorption and emission interactions. Given the principles enumerated above for the photoelectric effect, one can see how, at sufficiently low intensities, there will be a predominance of asymmetrical electronic emission and absorption-detection events. For example, at sufficiently low intensity, a 50/50 beam splitter has a probability of emitting light amplitude only in one direction (100/0); say from a single e-quant absorption/emission in the beam splitter in that direction or from the chance emission of a few e-quants in that direction. Likewise, even with many e-quants emitted simultaneously in various directions by the beam splitter, there is still a significant probability that unequal amplitudes will arrive at R and T. Even if the amplitudes delivered to R and T are identical in strength and phase, they will still superpose with unequal background amplitudes at each detector. In addition, only those electrons that are freed in the photomuliplier after absorbing an e-quant are counted. This detector inefficiency becomes more significant at low intensities. Only with very high numbers of e-quant emissions in all directions will this quantum "graininess" disappear and the classical picture be obtained. As argued above, it is our lack of knowledge of these contributing factors that necessitates QED's wave-statistical treatment.
5. **Unjustified Assumptions about E-quant Emissions:** The experimenters' belief that only one or two photons are being emitted by electrons in a source in a given direction or

directions, at a given moment, is unjustified. Not only do they have no independent way of knowing such a thing, but it is highly improbable, and practically impossible. They are directing a laser beam at a crystal with a very high number of atoms (~10^{22} atoms/cm^3). They are producing unknown, probably very high numbers of e-quant absorptions and emissions in all directions throughout the duration of the laser pulse or Gate window. The e-quants produced at different locations and times in the crystal will have differing phases as they spread and superposition throughout the crystal and the surrounding space. Since these experiments use visible light, the quanta spread much more with distance than x-ray or gamma radiation (How much spreading occurs with e-quants of various frequencies may be determinable by well-designed experiments.) All statements about emissions are nothing but inferences from detection events using some theory; and the flying photon theory doesn't work.

6. **Detected E-quants are not Identical to Emitted E-quants:** As per QED, the e-quants absorbed are the product of all light wave amplitudes of a certain frequency and at a certain phase, from all sources, impinging upon electrons in the photomultiplier throughout the Gate interval. The e-quants emitted by the source undergo amplitude attenuation by spreading and their waves are scattered by multiple absorptions/re-emissions by atoms in the air, lenses, filters, beam splitters, mirrors, etc. Detections result from the superpositioning of all these waves of various phases with background waves. In general, many more e-quants must be emitted by the source in the Gate interval than are eventually detected at G, R, and T. *The e-quant detected is not the same e-quant that was emitted; it is a different wave-packet produced by the superpositioning of all waves from the source and the background.* Again, x-ray and gamma-ray emissions and absorptions over short distances in a vacuum may be a possible exception to this rule.

7. **Low Intensity Light Must produce AntiCorrelation:** In these low-intensity "photon" demonstrations, there are large numbers of "dark counts" (~250cps in Thorn et al.). This means that detections require *no input from the source at all*. Background radiation alone is able to produce high numbers of e-quant absorptions in the photomultipliers, satisfying $g^{(2)}(0) \approx 1$. Therefore, to produce the additional anticorrelated detections, the source needs only to supply *some minimal amount of additional amplitude*, of the

right frequency and phase, at the right time, to superpose with background amplitudes upon an electron in the Gate and at R or T. Notice that in order to produce coincidences at R and T simultaneously requires *twice the amount of amplitude* from the source than needed to produce a single detection. Logically, if one keeps reducing the source intensity, eventually one must eventually get a marked preponderance of single counts over RT coincidences. Consider that *even if* approximately equal light amplitudes do arrive at the Gate and the beam splitter simultaneously, then R and T, after the beam splitter, must each receive less than half that same amplitude (beam splitter efficiency is <100%). At low intensities, the beam splitter is highly unlikely to send identical amounts of source-amplitude towards both R and T. Therefore it is highly unlikely that sufficiently low-intensity source emissions will produce simultaneous clicks in G, R and T above the dark count rate. GR and GT coincidences will be produced much more frequently than GRT coincidences due to all the *quantum deviations from classical symmetry*: deviations in amplitude and phase of waves beamed in both directions from the source, deviations in light scattering by all matter in the vicinity, deviations from 50-50 amplitude distribution in the beam splitter, deviations in the background amplitudes impinging on G, R and T, and deviations in the absorption-detection function of the photomultipliers.

8. **The Photonic Interpretation of Quantum Phenomena Requires Magic:** In these anticorrelation and other "photon" demonstrations and experiments, scientists ignore the counsel of Feynman and others. They presume to know what cannot be known: that their source is producing a single light particle at a time, that travels in straight lines to exactly where they need it to go; that bounces" off a mirror, "decides" to go this or that was at a beam splitter, "sheds some "energy" in a filter, gets "tipped" by a polarizer, and finally arrives at the detector to produce the additional photoelectric count that is observed. Only by magic could any of this happen. For instance, how can particles of light pass through millimeters of glass ($\sim 10^{22}$ atoms/cm^3) or other solid material (solid with electronic wave-structures) and emerge unchanged, with new "instructions" as to where to go? The photon theory of light is in fact contradicted by all known evidence and is incompatible with QED; it is complete nonsense. The behavior of light in all known circumstances, macroscopic and microscopic, can only explained by wave theory.

7. CONCLUSION

We can and must go beyond QED's observer-based accounting model and attempt to explain the physical nature of quantized light-matter interactions. The evidence is consistent with the theory that light consists of waves, and that electrons are wave-structures absorb and emit light directionally as wave-packets. Once emitted, these e-quants spread in space in proportion to their wavelength and superposition with all other ambient waves. Photomultiplier clicks are not caused by single e-quants that arrived intact from the source, but are the product of an extremely complex superpositioning of waves from many source e-quants, attenuated and scattered, with background waves. All talk of flying photons and the observer's knowledge of "which way the photon goes" is irrational. Interpreting any phenomenon or experiment according to the false flying photon theory produces nonsense—the "quantum spookiness" of double slit, delayed choice, quantum eraser, entanglement, quantum computing, teleportation, and non-locality experiments. When physicists try to make sense of the photonic nonsense, they are forced to produce more bizarre theories like observer-created reality, virtual particles, superluminal information transfer, holographic reality, and parallel universes. Drop the flying photon theory and all the nonsense, confusion, and unreality disappears. We must expunge "photon" from the scientific lexicon. I propose that it be replaced with "e-quant" as described in this theory.

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Résumé

Électrodynamique Quantique (EQ) n'est pas une théorie de causalité physique, mais seulement un modèle probabiliste de prediction qui etait modifié comme necessaire à corresponder aux observations. Contrairement à la croyance populaire, EQ ne modele pas la lumière comme des particules volantes; mais plutôt commes des onde-amplitudes de probabilité qui se propager en toutes directions de la source—par contractions et tours. Où les amplitudes superposent constructivement est où les événements de detection lumineuse est plus probables à surgir. Le modèle d'EQ soutenit la théorie présenté ici que la lumière est des ondes et que les électrons sont onde-structures électromagnétiques qui absorbent et émettrent des onde-paquets discrètes (e-quants). Les e-quants sont émettres dans une direction, et alors commencent à diffuser en espace et superposent avec le rayonnement de fond comme toutes des ondes libres. Une absorption d'un e-quant est produite par superposition complexe sur un électron de toutes les ondes de la source et du fond. L'e-quant détecté est rarement, si jamais, l'e-quant émettre. Cette onde-théorie de la lumière et des électrons comprend les phénomènes connues; y compris l'électrodynamique classique, l'effet photoélectrique, l'Effet de Compton, photon anticorrelation, et des autres expériences quantiques.