Light is a Wave

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Abstract
The evidence is clear: neither light nor electrons are particles. Both are wave-phenomena. Light is a spreading wave in a medium. The photon is associated with the wave-structure of the electron, it is the unit of wave-energy that is absorbed or emitted by an electron. Planck's constant, h, is an electronic structure constant and does not apply to freely propagating light itself. The electron is not a particle associated with an electromagnetic field, it is the electromagnetic field. It is as large as its field. Electrons continuously absorb and emit waves. The author will demonstrate that blackbody radiation, the photoelectric effect, the Compton effect, and the qualities of x-ray and gamma radiation are all best explained by the wave theory of light and electrons. The analysis reveals that there is a highly energetic background EM radiation field in all locations (vacuum fluctuations). Light is emitted directionally from an electron, and immediately begins to spread by spherical wavelets from every point on the wave front. The waves absorbed by any electron do not come only from the known source but from the superposition of source and background waves of the same frequency.

Key words: light, paradox, photon, quanta, Quantum Theory, Relativity, space, waves

1. Particle or Wave?

In 1896, most physicists believed that light was a wave in medium, the electromagnetic aether. The wave theory was necessary to explain many aspects of light: its wavelength and frequency, its invariant and extremely high velocity, and its interference properties. Light was thought to spread spherically from its source. Thirty years later a dramatic shift had occurred; most physicists agreed that light was a particle.

Physicists had discovered several phenomena in the microscopic world that could not be explained by the current ideas about light and matter. The radiant energy exchanged among atoms in a blackbody was found to be quantized. X-rays and gamma rays, at first not considered to be light at all, appeared not to spread at all in space. The entire quantum of energy released was taken up by a single atom at some distance. The same phenomenon was seen with visible light in the photoelectric effect. In the Compton effect, x-rays appeared to conserve linear momentum in their interactions with electrons. In 1923, Louis de Broglie formulated his theory that both light and matter have wave and particle characteristics. We now have a highly successful statistical model of light/matter interaction, Quantum Electrodynamics (QED), that relies upon wave concepts and mathematics to predict observable particulate events.

At this time we know much more about light and matter than did the researchers of the early 20^{th} century. We can attempt to formulate a more complete physical model to explain in just what way light and matter have wave-like and particle-like qualities. It now is certain that matter is composed of waves organized into a persistent structure, and that freely propagating light consists of propagating waves without a particulate structure. The wave theory of light eliminates the paradoxes caused by the particle theory, and unites the macroscopic aspects of light with the microscopic. Quantization is not a characteristic of light itself, but of the interactions of light and electrons. It is the electronic wave structure that is quantized and can absorb or emit specific wave-quanta. Light, once emitted by an electron does spread, but not spherically.

Many of the characteristics of electromagnetic radiation can only be explained by wave theory (See table 1). There are a few phenomena that appear to be due to the transfer of a discrete quantum of light from one electron to another across macroscopic distances. In order to reconcile all aspect of light, what is needed is a coherent wave-based explanation of blackbody spectra, the photoelectric effect, and the Compton effect. The remainder of paper will demonstrate, not only that these phenomena can be explained by wave theory, but that wave theory is the best explanation.

Explains or can accommodate:	Wave	Photon
Wavelength and frequency	**Yes**	**No**
Invariant velocity indep. of source velocity	**Yes**	**No**
Spherical spreading from every point	**Yes**	**No**
Interference, diffraction	**Yes**	**No**
Macroscopic wavelengths (e.g radio waves)	**Yes**	**No**
Laser	**Yes**	**Yes***
Blackbody spectrum	**?**	**Yes***
Photoelectric effect	**?**	**Yes***
Compton effect	**?**	**Yes***

***Requires the wave concepts to model and predict photonic events**

Table 1

1.1. The Photoelectric Effect

Early in the 20th century scientists were puzzled by the interactions of light and matter. In the case of radiation within a blackbody, the classical theory of light and matter predicted an "ultraviolet catastrophe" at high frequencies that did not occur. It was thought that EM waves caused particle-like electrons to oscillate, and that their oscillations produced more waves. Max Planck realized that he could eliminate this discrepancy by treating the energy as if it were a discrete variable instead of a continuous variable. As the simplest possible fit for the data, he obtained $\Delta E = h\nu$, where h was a proportionality constant describing the interaction of radiation and matter. Planck himself believed that it was the light-matter interaction that was quantized, and not light itself.

In the photoelectric effects, scientists noted three features that appeared to be inconsistent with the wave theory of light: (1)

1) **Frequency Dependence:** The kinetic energy of the ejected electrons depends only on the light frequency, not on the intensity.
2) **Frequency Cut-off:** No electrons are ejected when the frequency is below the cut-off frequency, no matter how intense the radiation.
3) **No Time Lag:** No time lag is observed as would be expected according to classical wave theory. Wave-energy should be uniformly distributed over the wave front, so it should take a considerable time for a small electron to absorb enough energy from the wave front to be ejected.

However, there are aspects of the physical situation that were not known, or not considered by scientists at the time. Given the additional information we have gained about the nature of light and of electrons in the intervening years, it is possible to formulate a wave-based theory of this phenomenon:

1) **Electrons are wave-structures:** An electron, bound or free, is not a simple particle, but is an extended EM wave-structure. It is not a particle associated with a field; the electron is is EM field. An electron is as large as its influence in space.

2) **Quantized Electronic Structure:** The amplitude and spatial extension of an electron's waves are fixed by its structure. The free electron's momentum is correlated only with the length of its waves (de Broglie relation: $\rho = h/\lambda$).
3) **Quantized Wave-Energy Exchange:** Given its wave-structure, an electron can absorb or emit EM waves only in discrete packets or quanta. The physical parameters of the quantum, its length, width, and amplitude, are fixed by the electron's structure. Only the frequency varies and determines the amount of wave-energy of the quantum. Planck's constant, h is an electron-structure constant, it does not describe freely propagating light.
4) **Free EM waves are not Quantized:** When an electron emits a quantum of light, it ceases to exist *qua* quantum. Its EM waves spread by diffraction.
5) **Directional Emission of Quanta:** The light emitted by an electron is directed, as in a collimated beam. It does not spread with spherical symmetry and therefore it does not obey the inverse square law. The higher the frequency of the radiation, the less the diffractive spreading, and the more "particle-like" is the emitted wave-train. The wave energy is concentrated into a small area outside the emitting electron.
6) **Energetic Background Radiation:** In any 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, though usually undetected, creates a highly energetic EM background (quantum or vacuum fluctuations). An absorbed quantum is the product of the superposition of source and background waves of a given frequency upon the receiving electron.
7) **Non-Interference of Waves:** EM wave-energy is not destroyed by interference. Waves pass through on another without suffering any change. Therefore the EM background is much more energetic than previously assumed. This wave energy is revealed only when waves of the correct frequency superposition upon an electron producing an event that can be detected.

Thus are the objections to wave theory answered:

1) **Frequency Dependence:** The momentum of the ejected electrons depends only on the frequency of the absorbed waves because the other physical parameters of the quantum of light that an electron can absorb—the length, width, and amplitude—are fixed by the structure of the receiving electron.
2) **Frequency Cut-off:** Increasing the intensity of the radiation increases the amplitude, but this cannot induce a quantum absorption if the light is not in the frequency range that can be absorbed by the receiving electron.
3) **No Time Lag:** The source radiation is emitted directionally, with less diffractive spreading at higher frequencies. Therefore a significant amount of the quantum's energy arrives at the target electron. The waves that the electron absorbs do not come from the source only in most circumstances, but are the product of the superposition of source and background waves. Since the electron is as large as its EM field in space, its reaction cross-section is much larger than generally assumed.

These principles are routinely illustrated in laboratories. In an article describing a low-light experimental setup, [(2)] the photoelectric detectors registered "dark" counts even when the source was not operating (background EM radiation). The "photons" from the source were then filtered to the intensity of one-tenth "photon" (not an indivisible particle). This filtered, subphotonic EM energy was sufficient, even at a distance of one meter, to produce the additional photomultiplier counts needed for the experiment. (directional emission plus superposition of source waves and background waves.)

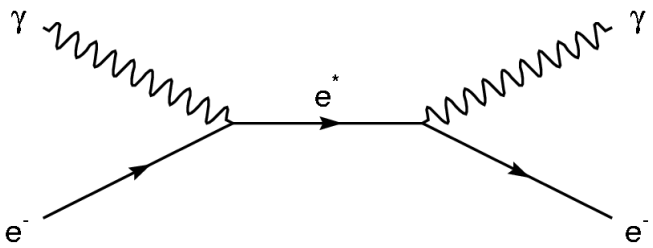
Experimenters have given us some glimpse into the physical size of electrons. An electron bound to an isolated hydrogen atom was detected, by its scattering of light, at a distance of several centimeters.[(3)] The experimentalist and theorist Carver Meade asserts that electrons are waves that expand to fit whatever container they are in. He claims that it is easy to make an electron that's 10 feet across, and electrons in super-conducting magnets are a mile long.[4]

1.2. The Compton Effect

Historically, the discovery of the Compton effect convinced physicists that all EM radiation was composed of flying particles. In his experiments, Compton allowed x-radiation of a sharply defined wavelength, λ, 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, λ', being longer by an amount that varied with the angle at which the scattered x-rays were observed, $\Delta\lambda = \lambda' - \lambda = \lambda_C\,(1 - \cos\theta)$. This became known as the *Compton shift*. The Compton wavelength was $\lambda_C = h/m_e c$. The unmodified x-rays were thought to be scattered by electrons that remained bound to their nucleus, while the modified x-rays were scattered by electrons that were freed. Subsequent experiments confirmed that the direction and momentum of the freed or recoil electrons were consistent with the direction and increased wavelength of the scattered x-rays. Momentum was conserved. Compton and others interpreted this interaction as requiring a billiard-ball type collision between two particles—a photon and an electron.

Since the x-ray scattering did not follow the rules of Thomson scattering but was quantized, it was concluded that the incident x-radiation could not be a classical EM wave but had to be a particle. Once again, we shall see that the fact that the effect seems difficult to explain using conventional ideas about light and electrons does not imply that light consists of flying photons. Consider that:

1) What is measured is a longer wavelength in the radiation emitted by recoiling electrons. Wavelength is a feature of waves, not of particles.
2) This is no "collision between billiard balls". Our best quantitative model of this interaction, QED, asserts that both the bound and the freed electrons *absorb* a quantum of radiation *and then re-emit it*. Thus the phenomenon is consistent with the model of electron-light interaction described here. Observe the Feynman diagram for Compton scattering:



3) The scattered x-rays are detected by a photoelectronic detector, and we have shown that this does not require the flying-photon hypothesis.
4) Any physical model, whether wave absorption or particle collision, will yield the same calculated results at various angles as directional energy or motion must be conserved in *any* physical system. In this case, the increased wavelength is caused by the Doppler shift in the light emitted by the recoiling electron.[5]

2. Quantum Electrodynamics

Quantum Electrodynamics (QED) is the highly successful and accurate method of predicting photonic events. Fortunately we have a clear presentation of its ideas and methods by Richard Feynman in his book of lectures titled *QED*.[(6)] Feynman explains that QED attempts only to describe and predict observable photonic "events"—the quantized, photomultiplied interactions of light and electrons.[(7)] In QED, sources produce not light waves, but probability waves, not EM wave amplitudes but probability amplitudes.[(8)] These probability amplitudes are added at a given point in space, then squared to give the probability of an event, just as wave amplitudes would be squared to give the wave energy at that point. Mimicking the propagation of light, QED adds the "shrinks and turns" of probability arrows for all possible photonic paths from source to target. The amplitude of the probability waves shrink according to the inverse square law, and they rotate in space according to the frequency. The summation of the resultant "arrows" at any given point in space determines the wave-energy at that point, and therefore the probability of a quantum being absorbed there.[(9)]

QED uses Schrödinger's wave functions and wave equations and treats light just as if it were a spreading wave in a medium! QED is a positivistic, instrumentalist application of wave theory to the electronic absorption and emission of light. It is a mathematical short-hand method for predicting the wave energy that a given source will produce at a given point, and therefore the probability of a quantized electron-light interaction at that point. The probabilistic method is required because there are unknowns that cannot be included in the calculations: the direction of the emission of any given quantum of light, and background radiation of and given frequency at any point.

Since QED works to account for light-electron interactions, its success supports the wave theory of light. Feynman admits that wave theory can explain the phenomena treated by QED, but he asserts that , "the wave theory cannot explain how the (photomultiplier) detector makes equally loud clicks as the light gets dimmer."[10] For this reason alone, he concludes that "light is made of particles".[(11)]

What does Feynman say about why QED uses wave theory, what a photon is, or why Nature works this way? He asserts that the only criterion of a good theory is whether its predictions agree with experiment. QED does not actually model the movement of photons but only predicts events—observable quantized interactions of light and matter.

He admits that there is no actual particle of light moving from point to point in space, yet he continues to speak of the photon as a real particle. He understands that within QED it is absurd to ask "which way the photon goes", yet he finds himself thinking in those terms at times. He states that in QED one can only say that the photon has an amplitude to go this way and amplitude to go that way, and where the amplitudes oppose each other no photon will go.[12] Realizing that the flying photon makes no sense as a physical hypothesis, Feynman concludes that Nature is absurd.[(13)] He states that because of this absurdity, physics has given up on trying to find physical models to explain the phenomena.[14] Yet he also claims that QED is a description of "Nature".

Feynman's confusion, and the absurdity produced by QED arise from a simple error: that of failing to create a working theory of light and electrons.

2.1. Electrons

The source of strangeness of quantum phenomena is not light itself, but the wave-nature of electrons. Electrons were once thought of as particles, little balls associated with an electric field. Now a vast amount of experimental evidence clearly indicates that they are extended EM wave structures. They are not particles in any conventional sense of the word. As wave-structures, we would expect electrons to be able to incorporate ambient EM waves into their structure, and also to expel waves. Electrons are composed of light. High frequency light can produce electron-positron pairs, and the annihilation of an electron produces only light. Electrons do not participate in the weak or strong forces. Light is composed of alternating electrical and magnetic fields. An electron may have its charge due to its wave's electrical fields being uniquely arranged so that all "negative" vectors are directed outward from the center, while the "positive" vectors are oriented internally. Thus the electron has a negative charge on the outside and a positive charge in the inside.[15] In positrons the waves have the opposite orientation. EM "repulsion" between two electrons may be the result of the interference of two wave-structures and their opposing electrical fields in space. The presence of spin ($^{h}/_{2\pi}$) and electromagnetic moment in electrons indicates that the EM wave-energy propagates around an axis; that there is an axial symmetry.

Consider the motion of electrons. Free electrons cannot remain at rest in space but propagate through space with a velocity that is proportional to their wave frequency. Their momentum is described by $\rho = {}^{h}/_{mc}$. It appears that electrons "swim" through the wave medium. The higher their frequency the faster they swim. They will tend to swim in a straight line at constant velocity in the medium unless diverted by an EM field. When a free electron absorbs light, it incorporates the additional waves, and therefore has a higher frequency and velocity in space. To slow down, it must emit waves, decreasing its own energy and frequency (*Bremsstrahlung* radiation). Free electrons in metals can absorb waves and acquire enough momentum to escape the metal's surface.

The association of nucleons and electrons forms atoms. In atom-formation, it appears that the electronic wave structure somehow expands to surround the nucleus; creating a new composite entity that is stable. The electron's waves take on new configurations that we describe as orbital shells. Each electron "orbital" is a configuration of the electron's waves that is stable at that distance from the nucleus. The more waves an electron has,

the larger the "shell" it must inhabit around the nucleus. When an electron bound to an atom absorbs waves it expands into a higher shell—it becomes a larger wave-structure surrounding the nucleus. If it emits the extra waves, it shrinks in size and falls into a smaller configuration closer to the nucleus. A nucleus-bound electron can also absorb enough waves to expand to the point that it escapes the attraction of its nucleus.

3. The Electromagnetic Medium

To be completed.

4. CONCLUSION

The assumption that all EM radiation, microcosmic and macrocosmic, is composed of waves freely propagating in a medium according to Huygens principle, and that electrons are EM wave structures eliminates all the paradoxes of quantum theory and eliminates the current schism between classical and quantum electromagnetics. The distinction between classical and quantum electromagnetics is not the size of Planck's electronic structure constant per se, but the fact that Quantum electrodynamics deals with the interaction of light with the electron's internal structure where as classical electrodynamics (e.g. radio waves) does not. Classical electrodynamics deals with macroscopic EM fields and waves in space produced by the translational motion of charged particles. Quantum electrodynamics deals specifically with the electronic/positronic absorption and emission of light and with other microscopic physical phenomena involving the electronic/positronic structure.

Viewing both light and electrons as waves eliminates the paradoxes of quantum theory and many of its strange qualities. The Heisenberg uncertainty relationship now is seen a natural consequence of treating waves as localized particles. The electron in a nucleus has not sharp location. When we "localize" and electron with some instrument, we are simply causing it to product some change in some apparatus at a location, this is not where or what the electron actually is.

Like the theory of evolution by natural selection, a working theory of ethereal space would increase our understanding of the Cosmos as a natural, self-contained, self-organizing physical system and would reduce the need for the hypothesis of an extra-Cosmic creator-God. Ether theory thus follows Copernicus' and Darwin's theories as yet another challenge to traditional theism. Like the Copernican and Darwinian theories, ether theory also removes man the observer and his "spirit" from the center of the Cosmos and from theoretical physics. Indeed, it takes Darwin's idea of the natural evolution of the species one step farther—to the natural evolution of the entire physical Cosmos and all its phenomena including man and his experiences. Darwin understood too well the destructive potential of his own limited theory of the evolution of the species including man. He became ill as he was torn for years between his desire to publish his theory and his wish to avoid offending Victorian society and possibly destroying its very foundations. Imagine the impact of a theory that describes the evolution of all physical phenomena from a single Cosmic substance! It is the ultimate anti-anthropocentric revolution! We are not the product of a Mind-God but of the natural evolution of Cosmic space itself! We thus can understand why Newton equated God with space, and why both Newton and Einstein, theists, decided to suppress and evade any further discussion

of ethereal space. A working ethereal theory of the Cosmos will discard theistic and Relativistic mysticism and produce a revolution in our understanding of the Cosmos and ourselves.

As astrophysics could not advance until Copernican heliocentrism replaced the observer's geocentrism; as biology could not advance until Darwinian evolution replaced observer-projected creationism; so physics cannot advance until etherism replaces observer-based atomism. Mankind must give up yet one more religious fantasy. We must continue down the path of understanding. Of course, as in the Copernican and Darwinian revolutions, embracing etherism brings with it great uncertainty and unease, for mankind has admit his ignorance of natural phenomena and face a whole host of new questions that he is currently ill-equipped to answer.

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