Photon Termination at a Point without the Particle Concept

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Abstract

Wave-particle duality is considered for the photon only. It is argued that the photon's wave nature is indisputable unlike its particle nature. Photon as particle largely depends upon photon termination at a point with the analogy then made to particle impact. An alternate scenario for photon point termination is offered; a side benefit of this is a possible alternate view of photon entanglement.

1.0 Introduction

How can light be both a particle and a wave? This question has been with us for over a century and it is hard to detect any progress toward a resolution. Most theoretical physicists and philosophers of physics have moved on to other, more career-rewarding issues; wave-particle duality has become "baked-in" to their world view. Modern optics and photonics have spurred many duality experiments with light, but this research rarely ventures into theoretical issues. We are left with trying to adapt to radiation the usual interpretations of quantum mechanics.

The Copenhagen interpretation does not attempt to explain radiation duality except to insist that it is both fundamental and beyond our ken. It is the experimenters choice of measurement devices that determines whether waves or particles are detected. It has been said that Complementarity solves the dualism dilemma "…by simply accepting both of the dilemma's horns [1, p.123]."

The de Broglie-Bohm pilot wave theory is best suited for describing how rest mass particles (e.g., electrons) are guided by the wave function. The theory has been applied to the photon [2], [3], [4], [5], but various issues arise. For example, Schrödinger's wave equation applied to radiation devolves into Maxwell's equation. And it is not clear how the photon can have a "complex and subtle inner structure" [6, p.37] as Bohm's mass-bearing particle has.

Quantum Field Theory (QFT) says that all particles, including the photon, are excitations of an underling, quantized field. Supporters [7], [8], [9] of this view claim it resolves wave-particle dualism. But these quantized fields are operator valued and "…it is exceptionally unclear which parts of the formalism should be taken to represent anything physical in the first place [10]." Interpreting oscillatory field modes as particle-like is to tease the discrete out of the continuous; it seems a bit of an argument of convenience rather than an argument of physics. Despite its many successes, QFT is not well adapted to explain radiation dualism.

2,0 Photon as Wave

Electrons and photons both exhibit dualism when traversing a double slit. This prompts everyone to assume there is a common explanation for both. Perhaps there is, but that is a larger question. Our purpose here is more modest and there is some value in treating the two cases separately. It is not clear how or if the wave function and Heisenberg uncertainty apply to the in-flight photon whereas they certainly apply to the electron.

So our dualism focus here is just on the photon. We begin with two questions:

1) **What evidence tells us the photon is a wave and what tells us it is a particle?**

2) **When the individual photon diffracts (double slit, pinhole) and follows multiple paths in space, why is it that photon kinetic energy remains undiminished?**

Regarding the first question, the wave (continuous) nature of radiation seems indisputable. Since EM radiation is oscillatory, its progression in space yields the waveform. Radiation exhibits interference, diffraction and superposition. Radiation waves are on secure grounds mathematically, both via wave (physical) optics and Maxwell's equations.

The particle nature of radiation is not mathematically grounded, at least nothing comparable to Maxwell's equations. Radiation is quantized and delivered (to matter) in discrete energy chunks, but that does not prove the photon is a particle. The identification of the photon as a particle seems to rest upon its delivery of energy and momentum to a point in space and time. The analogy with particle impact is obvious, perhaps too obvious. It was certainly decisive for Richard Feynman who cites the individual arrival of photons on a detector and concludes: "[w]e know that light is made of particles… [11, p.14]." But this reasoning-by-analogy is a classic case of underdetermination.[1] While it is difficult to argue that the wave nature of radiation is underdetermined, the opposite is true of the particle nature of radiation.

So the answer to question #1 above is that the wave nature of the photon is convincing whereas its particle nature is open to question. Presently an alternate explanation of radiation's

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[1] "For any theory, T, and any given body of evidence supporting T, there is at least one rival (i.e., contrary) to T that is as well supported as T [12, p.271]."

"discrete arrival" will be made. But that explanation hinges on the second question posed above. How can the photon diffract and yet keep its kinetic energy intact?

3.0 The Photon's Two Identities

A stationary (inertial) particle progresses (persists) over time. Different observers over this time progression perceive this self-same particle. We say that the time-separated observers have this particle in common.

Imagine a single photon progressing over space. Different observers over this space progression can (potentially) receive this self-same photon. These space-separated observers have the photon in common. Assume this photon then traverses a double slit (or pinhole). Suddenly the photon has multiple paths in space all with differing probabilities of reception. In spite of this, observers (detectors) placed on all of these paths can (potentially) receive the one and only photon with the original energy and momentum. All of this tells us a couple things.

First, space devices – pinholes, slits – will fractionate photon probability-of-reception, but not photon kinetic energy. This means that the photon has two identities, energy vs. probability, that behave differently. Since probability is associated with (random) release of what is stored, this suggests the photon has a kinetic identity (as kinetic energy) immune to diffraction and a potential identity (as probability) prone to diffraction.

Second, entities are common to (shared by) observers if the observation is made in one dimension, space or time, and the entity resides in the opposite dimension. Thus space-residing rest mass (a particle) is common for observers at successive time locations. We say that rest mass is orthogonal to time and what happens there, namely successive measurements or observations in time. So an entity is orthogonal to a dimension when it does not reside in that dimension. And that entity residing in (occupying an interval in) one dimension is common for observers in the opposite dimension.

Since the photon's kinetic energy is common for multiple observers in space, it must be orthogonal to space. We conclude that photon kinetic energy does not reside in space where it might fractionate or dissipate.

- **The photon has two identities**
- **The photon's kinetic identity, kinetic energy, is in time.**
- **Photon kinetic energy is common to (shared by) multiple observers on space paths.**

- **The photon's potential identity, probability, is in space where it progresses and possibly diffracts on to multiple paths.**

4.0 Photon Kinetic Identity as Pure Oscillation

Placing photon kinetic energy in time resolves the energy dissipation issue of question #2 above. It is also less radical than it appears. We are not positing a new entity, just taking something regarded as a quantity (radiation kinetic energy), treating it as one facet (identity) of the photon entity and giving it a presence in a dimension. There is a certain symmetry in this. Matter consists of existing (rest mass) quanta residing in space. Radiation consists of occurring (oscillatory) quanta residing in time. In each case a quantum occupies an interval in the dimension where it resides: space for the rest mass of the particle; time for the energy of the cycling photon.

From classical physics we inherited the concept of kinetic energy as a simple quantity possessed by matter-in-motion. But this view does not work well for the photon. If the photon is both particle and wave there is no easy way to conceive of photon kinetic energy as an attribute. The reader might argue that photon kinetic energy is a quantized whole that must terminate with its energy intact. But portions of this quantized photon disperse in space due to its wave nature. Somehow the quantized energy must avoid this dispersion and the most straightforward way to do this is not to reside in space, just as rest mass does not reside in time.[2]

Kinetic energy is created by work done. Doing work on a charge creates something without rest mass; it creates photon kinetic energy which is oscillation not involving anything existing. <u>Photon kinetic energy is pure oscillation residing in time</u>. Of course, as energy it has a quantitative measure as well.

Pure oscillation with no rest mass involved is well known in physics. Vacuum state fluctuation in QFT is the oscillation of "nothing" or oscillation from "nothing." A more speculative example is string theory where strings are filaments of vibrating energy. But these theories continue to tie pure oscillation and its energy to the space dimension: QFT's oscillation invokes virtual (space-navigating) particles; the strings of string theory are the Planck-scale constituents of material particles in space. Energy oscillation devoid of rest mass (i.e., radiation) should be in time, not in space; it is still accessible to (common for) observers in space.

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[2] Mechanics (and relativity) conditions us to think that everything resides in (has a defined location in) space and in time. That is not the case for a stationary rest mass nor for a photon. The desk you are sitting at resides in space and you can perceive it at different time locations. Those are locations of your perception events, not of your desk.

5.0 Photon Termination at a Point

Photons can only terminate on matter; this involves the transfer of time-residing photon kinetic energy to space-residing rest mass. This is possible because something residing in time (photon kinetic energy) is common for observers/objects residing in space. But the only way the two can meet/intersect is via an event which combines kinetic energy with rest mass. Ontologically, this is the intersection of occurrence (energy) with existence (mass) mediated by probability. This event/intersection is discrete in both space and time since the two actors are orthogonal in terms of where they reside. The transfer of time-residing kinetic energy to space-residing matter is quantized and event based; it cannot be continuous.

Photon reception delivers both energy and momentum to the target rest mass just as an impacting particle does. But there is a big difference between the two cases. A particle impacting on a material target is an event between two mass-based objects. Photon impinging on a material target is an event created by the intersection of ontological opposites, one mass based, the other not. This radiation absorption event is the inverse of the radiation emission event; both events feature an energy/momentum interchange without involving particle mass or particle trajectory. Photon reception on a target is governed in aggregate by the photon's waveform space-progressing potential identity, the exact nature of which: 1) remains unclear; and 2) cannot be covered in these few pages.

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6.0 Conclusions

We have seen that the wave nature of the photon is well-grounded both experimentally and mathematically. This is not the case for the concept of the photon as particle; the latter depends upon analogy with the impact of rest mass particle.

Rest mass resides in space. Having photon kinetic energy reside in time explains why such energy does not fractionate during photon diffraction. Photon kinetic energy is orthogonal to (and common for) multiple space observers; it is also orthogonal to its rest mass target explaining why any intersection must be discrete and received at a point (imitating impact).

Giving photon kinetic energy a presence in time is a big change from what we have been taught; but it is not unphysical, especially since rest mass has a presence in space. Even though photon kinetic energy resides (and oscillates) in time, this does not prevent it from interacting with material objects in space.

The discrete nature of photon termination can be explained without recourse to the particle concept. The latter is a simplistic analogy and stands in the way of a better understanding of radiation.

Appendix

It is unlikely that experiments can decide between photon kinetic energy as: 1) a mere quantity; or 2) as oscillation in the time dimension. When experimentation cannot settle the claims between competing theories, the only recourse is to look at which theory explains seemingly unrelated phenomena.

Bonding between like entities – such as two atoms – joins their kinetic identities in the dimension wherein they reside. Thus a sodium ion and a chlorine ion have rest masses that reside and bond in space. If photons have their kinetic identity in time, then under the right circumstances their separate kinetic energies should be able to bond (entangle) in time.

Assume you add energy to a calcium atom to create parametric down conversion. This energy promotes two 4s electrons to the (unstable) 4p orbital. The return of these the two electrons to the 4s orbital creates two (entangled) photons, one blue and one green in frequency. The blue and green photons are created in a cascade event making them time-adjacent; they retain their individuality (their frequencies) but their kinetic energies are bonded/entangled. Their creation sends out probability-of-reception waves for both photons in all directions.

If indeed photon kinetic energy resides in time, this makes photon entanglement less mysterious. The parallel with rest masses bonding in space is obvious: like entities bonding in their shared dimension, space for rest mass, time for photon kinetic energy. And there is an additional benefit/insight involving polarization change.

Polarization characterizes individual photons and is undefined for a union of two photons. But entangled photons may be received separately and reception of one defines its polarization thereby defining the other (anti-correlation).

The probability waves of the entangled photons fan out in all directions toward potential observers. But all space-separated, potential observers have the entangled, time-residing photon kinetic energies in common since all potential, space-residing observers are orthogonal to said energies (Section 3.0). And the polarization of these entangled energies is also common for (shared by) all possible observers; either: 1) undefined pre-reception; or 2) anti-correlated post reception. Hence space-separated observers sharing something in common (in time) do not have to signal polarization status change to each other.

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