# Gauge Symmetry and Invariant Features of Particles and Photons: Insights into Duality, Time's Arrow and Nonlocality

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**Abstract:**

Particles and photons appear to be total opposites; the former has rest mass which requires space to exist; the latter has kinetic energy which requires time to occur (oscillate). But they do share certain properties (e.g., quantization) that remain invariant when one is transformed (swapped) for the other. This gauge invariance is developed in some detail.
The symmetry between particle and photon turns out to be one of inversion. It is the equalities of special relativity that support this inversion and the accompanying invariances: mass transformed to energy; space transformed to time. The great advantage of these symmetries (inversions) is that they provide guidance for an object little understood (the photon) based upon an object well understood (the particle). On this basis, progress can be made in the understanding of some long-standing issues: wave-particle duality, time's arrow, the constant speed of light and nonlocality.

Keywords: gauge invariance, symmetry, time's arrow, nonlocality, wave-particle duality, double slit, delayed-choice experiment

## 1. Symmetry and invariance

Gauge (measurement) invariance is when a property stays constant over a transformation. Such invariance is regarded as symmetry. Symmetry currently pervades modern physics as "…the most dominant concept in the exploration and formulation of… fundamental laws…[1]." The Standard Model has been called "…a zoo of symmetries [2]."

Symmetry as a concept implies an ordered state or relationship, but it has broadened over the centuries from the geometric (Kepler's orbital symmetries) to the mathematical (Maxwell's equation symmetries) to space-time transformations between moving observers (those of Lorentz). Symmetry is now understood as a relation of invariance characterizing descriptions or laws under a specified set of transformations. There are no restrictions on these transformations or the invariant quantities involved. With no set rules for defining symmetry, physicists and mathematicians have been very inventive in proposing new relationships.

## 2. Types of transformations:

Some transformations involve the relationships between dimensions. An example is the Lorentz transformation that relates space and time measures between observers in different inertial systems. This is not a swap of one dimension for another; rather it is a sliding scale whereby different inertial observers divide up space and time differently. Other transformations are true swaps between dimensions or between similar entities (particles): electrons for neutrinos, up quarks for down quarks.

The equal standing of space and time in special relativity gets interpreted as interchangeability; one can be swapped for the other as a symmetric transformation. Hence the argument that rest mass advancing forward in space as well as in time should have its counterpart of moving "backward" in space as well as in time (getting younger in time). This transformation involves a swapping of dimensions (time for space) and of directions (backward for forward). There are problems with both of these swaps.

First, the issue with swapping directions is that an inertial particle has no kinetic energy (KE) making it stationary in space. A particle at rest in space has no forward or backward orientation. For space, the only objective directions – as will be seen – are three-dimensional expansion (e.g., of radiation, or of the universe) versus contraction.

A second problem is the swapping of time for space for a particle. This assumes that a rest mass particle has the same relation to time as it does to space. In fact, a rest mass particle resides in (occupies) space; that same particle does not reside in time. Taking an entity (particle) and comparing its movement within a dimension wherein it resides with its supposed movement within a dimension wherein it does not reside is not correct; it yields an asymmetry.[1]

### 2.1 Entity plus dimension transformation

The preceding indicates that one must take a holistic approach to an entity when looking for valid transformations. Any inversion (swapping) of dimensions (space and time) for an entity must take into account that entity's space and time dependencies; i.e., where it resides.

In addition, "entity" should be interpreted broadly to include any measurable, quantized object composed of mass or energy; hence the photon has dependencies upon space and time just as the inertial rest mass particle does. Both of these entities require space and time to function the way they do; the rest mass particle requires space to exist; the photon requires time for its oscillation cycles to occur.

The inertial, space-stationary particle and the time-stationary in-flight photon give the appearance of diametrical opposition, namely: quiescent rest mass versus oscillatory kinetic energy (KE); one advancing in time (the particle) with the other advancing in space (the photon). But all of these opposites – mass versus energy, space versus time – have been given equal standing within special relativity which suggests that this opposition actually constitutes entity-and-dimension inversion. In that case, entity swapping (photon for particle) requires dimension swapping (time for space).

- **The inverse of space-stationary rest mass requiring space to exist is the time-stationary photon requiring time to occur (oscillate).**

The transform from inertial particle to photon or vice versa preserves a number of symmetrical, invariant properties; at least seven to be precise. They will be explored presently, but first two overlooked aspects of entities must be covered.

## 3. Entity identity and functionality

[1]For his famous diagrams, Richard Feynman took two particles and assigned time forward to one (matter) and time backward to the other (anti-matter). This worked mathematically, but not in reality since time does not go backward, even for anti-matter. Existing and residing in space restricts an entity's directionality in time. Time advance is necessary for matter; space advance is necessary for energy (radiation); neither advance is reversable.

If you ask a physicist about the functionality of a particle, she will cite movement of, and forces acting upon, said particle. That a particle occupies and requires space is not regarded as a particle function nor does it even qualify as physics; and yet it is what the particle does to exist.

**Two identities**: It is an inertial particle's rest mass that resides in (occupies) space giving the particle a space location relative to some arbitrary reference particle. But while rest mass is a particle's first (essential) identity, the particle has a second (potential) identity by virtue of rest mass doubling as stored energy via $E = mc^2$. The inertial particle has an essential and a potential identity.[2]

**Two functionalities**: Traveling with a muon to render it space stationary, one would observe that the muon has a space-residing (occupying) functionality plus a time-progressing probability-of-annihilation functionality. For particles in general, their function in the time dimension is to progress toward release of stored energy via either photon emission or particle annihilation. Of course, the rest mass itself persists over time, but the active, temporal particle function is probabilistic release of what is stored. Particle functionality is: 1) in space (as rest mass residing); and 2) in time (as stored, releasable energy progressing).

- **A particle's essential identity, rest mass, resides in one dimension, space; its potential identity, stored energy, progresses in the opposing dimension, time, toward release.**

- **In general, residing in one dimension and progressing in the opposite dimension constitutes entity functionality.**

- **The space-stationary (inertial) particle and the time-stationary photon have two identities (essential and potential), two functions (residing and progressing) and carry out those functions in two dimensions (space and time).[3]**

This symmetry of inertial particle and photon is the most fundamental and extensive of all because it is the inversion of: (a) categories (exist versus occur); (b) entities (particle versus photon); and (c) dimensions (space versus time). It is a unique symmetry in that as an inversion it respects the dependencies entities have upon their dimensions, space and time.

## 4. Foundational symmetry and invariance

Features that are invariant between photon and inertial particle apply either to: the entities themselves (4.1); or the dimensions these entities utilize (4.2).

### 4.1 Entity invariance: mass versus energy

a) **Quantization:** Both rest mass and KE (radiation) are quantized.

b) **Transmutation:** The existence of the inertial particle may become the occurrence of the photon (annihilation). The occurrence of the photon may become the existence of the particle (pair production).

[2] Kinetic (unstored) is the opposite of potential (stored). But the former has two meanings, unstored and moving. Rest mass in these pages is not moving, hence the use of essential rather than kinetic as the opposite of potential.
[3] The goal here to understand the photon (esp. its use of dimensions) based on particle symmetry. Have patience…

c) **Entanglement:** Adjacent rest masses can bond together; adjacent photons can bond together (Sec. 12.).

d) **Storage of opposite due to E = mc²:** Inertial rest mass stores potential energy (intrinsic, thermal). The photon stores potential (relativistic) mass.

e) **Storage means an entity has a potential (stored) identity and an essential (unstored) identity:** The inertial particle's essential identity is rest mass; its potential identity is stored energy (thermal, intrinsic) progressing in time toward probable release.
The photon's essential identity is kinetic energy (KE); its potential identity is stored mass progressing in space (as a wavefront) toward probable release (reception).

### 4.2 Dimensional invariance: space versus time

a) **Stationary in one dimension:** The inertial particle is stationary in space; the photon is stationary in time (infinite time dilation).

b) **Progression in the opposite dimension:** The inertial particle always progresses in one direction (temporal advance); the photon always progresses in one direction (spatial advance-expansion).

c) **Progression at the maximum rate:** The inertial particle as pure existence (no KE) progresses in time (persists) at the maximum rate; if it moves its clocks slow down. If it can't progress in time, it ceases to exist.
The photon as pure occurrence (no rest mass) progresses in space at the maximum rate, the speed of light. If it can't progress in space, it ceases to occur.

The photon has always been a mystery to us. But identifying entity functionality (residing versus progressing) and defining the photon's symmetries with the inertial particle (above) finally provide some insights. It is now possible to see how the photon utilizes space and time and functions differently in each. Now on to what the photon is and what it isn't.

## 5. What the photon isn't

The photon is not a unitary entity; like any measurable, mass/energy entity, it has an essential identity and a potential identity. For the photon its essential identity is KE and its potential identity is potential (relativistic) mass. They behave differently; the former never diffracts in space, the latter does and collapses nonlocally upon reception. The photon is also not a particle. The symmetry between the photon and the particle is that of inversion, the swapping of opposites. The photon cannot be a particle; it is the occurring-energy opposite of the existing-mass particle.

The attachment physicists have to the photon-as-particle goes back to classical physics which was all about particles moving in space, hence: classical mechanics, fluid mechanics, statistical mechanics and celestial mechanics; all of which led naturally to quantum mechanics. Mathematically, mechanics is all about equations describing the space movement of particles over time, plus their energy and momentum as non-dispersing payloads. The wave nature of the photon does not support the payload concept, hence the preference for photon-as-particle.

Most physicists believe that reception of photon KE and momentum at a point constitutes proof of particle behavior. But this is really an analogy based on our (macroworld) experience; it assumes that KE can only appear as a particle payload, never (like a particle) on its own;[4] it is the particle mechanics of massy objects imposed on massless radiation. And particle mechanics when applied to radiation is necessarily inconsistent: it treats the particle and its essential identity, rest mass, as entities; but it treats the photon as an entity and then denies entity status to the photon's essential identity, KE.

The photon is often compared to the speeding electron; both display wave behavior, with the particle status of the electron implying particle status for the photon. This is another invalid comparison. We shall see presently that KE by nature is oscillatory; hence anything moving in space has KE, the oscillation of which creates waves. The photon and the electron are only comparable by their oscillatory KE; the rest mass of the electron makes it a particle; this is unrelated to the massless photon. Another false analogy.

Unlike the case for the photon being a particle, the case against doesn't have to rely on analogy and false comparisons. As the opposite of a real particle, the photon: 1) is massless; 2) has no defined space location (no trajectory); and 3) violates Galilean relativity. We overlook or excuse 1) and 2) and we cope with 3) via an ad hoc postulate (Sec. 11.). All of this to make radiation part of mechanics!

Physicists can treat photon KE as a particle payload because KE is quantitatively measurable and its value works within equations. And, of course, the photon as particle fits into today's dominant physics paradigm, matter moving in space. Currently, anything non-material – photon KE plus forces – must be a quantitative payload carried through space by real or virtual particles (bosons); this avoids the dreaded action at a distance.[5]

## 6. What the photon is

As noted, the photon's inverse, a particle, has two identities, rest mass (as essential) and stored/intrinsic energy (as potential). Each identity has a different function, residing versus progressing, and these functions play out in two different dimensions, space and time respectively. The photon is the same except that mass and energy switch places as do space and time.

A photon's potential identity – what it stores, namely potential-relativistic mass – progresses and expands in space as a wavefront. The wavefront of an individual photon is physically real since it can be manipulated in space via diffraction (in a slit) or bifurcation (in a beam splitter). As an $E = mc^2$ expression of photon KE, this wavefront is potential and therefore probabilistic in nature; its local intensity determines the likelihood of the release of photon KE (reception).

Entity functionality – residing versus progressing – always plays out in opposing dimensions. A material object (particle) has its essential identity, rest mass, residing in space while its potential identity, stored energy, progresses in time toward probable release. It follows that since the photon has its release probability progressing in space, then the photon's essential identity, its KE, must reside in time.

- **A photon's essential identity, KE, resides in one dimension, time; its potential identity progresses in the opposing dimension, space, toward release of what is stored.
The traditional view of the photon as a unitary object solely in space is wrong.**

[4] When an energy event lasting about $1.6\times10^{-22}$ seconds is detected at CERN, it is immediately dubbed a particle and given a name. KE must always be a payload; that and the ether theory is what the 19th century taught us.
[5] Action at a distance comes back to bite particle-payload physics in the form of nonlocality. See Sec. 12.

- **Photon KE residing and oscillating in time finally explains why devices in space (slits, beam splitters) can fractionate the probability paths of the photon without ever affecting its KE.**

Of course, making photon KE an entity on its own – much less putting it in the time dimension – is not aligned with current physics. It conflicts with the traditional assumption that KE is a quantitative payload of something more real, more "tangible," namely a particle.

The ontology of our current physics – derived as it is from classical physics – leaves us with a reality consisting of discrete objects in space, i.e., particle physics. Placing anything in the time dimension seems problematic, or worse; this despite everyone's (token) acknowledgement of the equality of space and time. Two immediate objections to anything residing in time come to mind: 1) how can photon KE have a presence on its own; and 2) how can anything be accessed if it resides in time?

### 6.1 Photon KE's presence as pure occurrence:

Photon KE appears when work is done on a charge; this work creates (constitutes) KE. Because the charge, as charge, has no rest mass, the KE created is "on its own." This KE simply occurs as oscillation without any space-located rest mass hosting it. This KE does not travel in space with the photon's wave since it can never be rarefied. With no rest mass involved to provide a presence in space, pure, oscillatory KE resides in time as its oscillation utilizes (occupies) time intervals.

To repeat, photon KE residing in time is the symmetrical inversion of inertial rest mass residing in space; they share an invariance (of residing/occupying) since each must occupy an interval in a dimension to have a physical presence; one to occur, one to exist. Pure occurrence without rest mass is not unknown in physics; vacuum state fluctuations are just that.

### 6.2 Accessing what resides in time:

Human experience leads us to believe that we have direct access to (rest mass) objects residing in space while whatever – if anything – may reside in time is inaccessible to us. Neither is true; we access both via events which are necessarily the conjunction of rest mass and KE.

Rest mass objects – your chair, your computer – are accessed by a perception or touching event. That is your only access to them. Similarly, photon KE is accessed by a reception event, namely photon KE as received on a rest mass detector: e.g., an electronic photon sensor or the retina of your eye. That which resides and exists in space is no more "real" or accessible than that which resides and occurs in time. Both are mediated through an event as the joining of rest mass with KE. Of course, as material beings in space we are partial to space-residing matter; for us, energy and time don't rise above quantity and interval, respectively.

## 7. Conceptual impediments

Granting photon KE entity status, whereby it resides, like any entity, in a dimension is neither unphysical nor metaphysical. Time, photon KE and the concept of physical entity are all included within current physics theory. The (big) change is to give each a different role in a new configuration, namely to equate energy with mass and let time host an entity just as space hosts an entity. This runs counter to our space-centric experience and all of our textbook learning; counter arguments will not be lacking. Among them are:

*There is no experimental proof for what is being suggested.*

Asking for experimental proof that photon KE resides in time overlooks how knowledge of the physical world is acquired. Our experiments depend upon space-residing, rest mass instruments that can only receive KE events. That cuts us off from any probing within the time domain; for what happens there we must depend upon our intuition and our ability to follow the hints that Nature provides (i.e., symmetry). As rest mass beings, operating in space with rest mass instruments, we have created a physics to align with that. We have interpreted radiation accordingly and then convinced ourselves that our instruments can detect any real entity in any dimension, which reduces in practice to particles in space. This is anthropocentrism; or maybe mass-space-existent centrism.

*Current physics has addressed and answered all the major questions regarding particles and radiation.*

Not true at all. Particle physics (QM, QFT, QED, the Standard Model) has bypassed or given up on major questions and left them as "features of reality," i.e., paradoxes. It has also relegated them to philosophy. Included, and covered below, are: wave-particle dualism; time's arrow; the double slit; the Mach-Zehnder interferometer; the constant speed of light; and nonlocality.

*Any new physics theory must be based on mathematics.*

Not true currently. Symmetry and invariance now seem to supersede mathematics as a guide to physics theory.

The devotion, even reverence, for mathematics is a consequence of the success it has shown for describing and predicting matter-in-motion and energy transfer. But foundational concepts in physics cannot be solved or proven via mathematics. That includes the conservation laws, inertia and Einstein's first postulate. Whether KE, as argued here, is (the essential identity of) an entity by itself or whether it is merely a quantitative attribute (payload) of particle entities cannot be settled by mathematics. Deciding between the two options is a practical matter: which gives us the most explanations, the fewest paradoxes and accords best with the symmetry Nature seems to favor.

*This is philosophy, not physics.*

Gauge invariance is physics, not philosophy. Classical physics grew organically without any thought given as to how entities (especially stationary entities) functioned or how they utilized space and time. The quantum pioneers simply continued that tradition. Einstein's special (and general) relativity began the process of looking at how matter and velocity affected space and time, but still from the point of view of mechanics. That inquiry needs to be extended, but with a clear distinction between stationary entities that keep mass and KE separate versus matter-in-motion which does not.

## 7.1 Summation and looking forward

A lot has been covered. So, take a deep breath and exhale; you are at the top of the mountain (of concepts); everything is downhill (easier) from here. To summarize:

- **The equalities within special relativity guarantee an inverted symmetry such that all entities have two identities (essential, potential) with different functions (residing, progressing) in opposing dimensions.**

- **This means that the photon has: #1) immaterial, oscillatory KE residing in time making it available for reception events; and #2) dependent, potential (relativistic) mass progressing as a wave in space.**

**Item #1 enables the discrete, namely KE point reception; item #2 enables the continuous, namely probabilistic waveform.**

Abstract concepts – especially those contrary to tradition – become easier when one sees them applied to specific problems or paradoxes. That will be the case here; please reserve judgment on photon KE residing in time until seeing how it applies to: 1) dualism; 2) time's arrow; 3) the double slit; 4) the Mach-Zehnder interferometer; 5) the speed of light; and 6) nonlocality.

## 8. Dualism, photon point reception and the photoelectric effect

**Dualism:** Since the photon is not a particle (Sec. 5.), it does not embody dualism. It is photon point reception that causes even the smartest people (e.g., Feynman) to (unconsciously) invoke the analogy with particle impact and assume (without proof and against [wave] contraindications) that the photon must be a particle.[6]

**Point reception**: The photon's potential identity progresses in space as a wave. This wavefront's local intensity probabilistically determines the likelihood of photon reception. This wavefront is an $E = mc^2$ expression of oscillatory photon KE making it dependent upon the latter regardless of the wavefront's spread and rarefaction in space. Being dependent, this *wavefront collapses nonlocally in space* at reception when its time-residing (orthogonal) source ceases to occur in time.[7]

The photon wavefront may touch many (rest mass) detectors without triggering reception. But when reception is initiated, an energy transfer event occurs as the intersection of the essential identities of two entities: rest mass detector in space and photon KE in time. These entities are mutually orthogonal and can only meet/transfer at a point/event. Such an event must be discrete and located in both of the two dimensions involved. It mimics particle impact with no particle being involved.

*Everyone* assumes the reception point defines the final space location of the unitary photon object delivering its payload energy; that is not the case. The reception point is simply the space location of the KE transfer *event* rather than the location of a received object that has arrived after traveling through space. This transfer event does not locate the photon object (its KE) in space any more than your desk perception event on Monday morning locates your desk (its rest mass) in time. Your desk residing in space and photon KE residing in time are simply available for perception/reception events in a dimension where they do not reside.

So, the photon reception event is the intersection of orthogonal rest mass in space with photon KE in time. The exact inverse of this is the photon emission event. People think of the photon emission event as creating a wave; e.g., a radio *broadcasting* antenna. But those same people think of a photon reception event as the arrival of a particle. It is the same radiation, going and coming; people choose whatever photon model seems convenient. And they never think twice about it.

**The photoelectric effect**: This has long been used to support the idea of the photon as particle. But it is really just a variation on the point reception argument plus quantization.

The photoelectric effect does prove that radiation's energy delivery is quantized and that a certain energy level is required to dislodge bound electrons. But interpreting quantization and point reception as particle impact is again an unreflective analogy with common experience; it assumes that KE can only be a particle payload which is contrary to the ontological equality of mass and energy: if

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[6] Richard Feynman: "We know that light is made of particles…something like raindrops…." [3, p.14]

[7] This nonlocal collapse in space of something potential yet also physical –we can alter it in space (e.g., diffract or reflect it) – is the best proof we have that space and time are orthogonal rather than merged/flat as spacetime.

mass can stand alone (exist) in space, then (photon) energy can stand alone (oscillate) in time. It is also at variance with the entity symmetry cited in Sec. 4: the photon cannot be a particle; it is the energy inverse of the massy particle.

Photon dualism arose because radiation waves rarefy and diffract yet KE arrives discretely. It has never been resolved. Physicists avoid the issue, accept it as a feature of radiation and move on which is understandable; they have new papers to write plus grants and tenure to obtain. Quantum field theorists try to square the circle; their discrete particles are excitations within a continuous field (in infinite dimensional Hilbert space). But to explain real interactions, QFT employs traditional particle concepts – a payload navigating 3-D space – for all their bosons, including the massless, diffractable, rarefiable photon.

## 9. Time's arrow

In special relativity space and time are regarded as equal, yet time always advances and space does not. Joan Vaccaro writes, "An asymmetry exists… in the sense that physical systems inevitably evolve over time, whereas there is no corresponding ubiquitous translation over space [5, Abstract]." Tim Maudlin agrees, "The passage of time is an intrinsic asymmetry in the temporal structure of the world, an asymmetry that has no spatial counterpart [5, p. 108]."

Both of these statements are incorrect because they confine reality ("physical systems" or "world") to material objects and ignore radiation. It is the blind spot inherited from the ontology of classical physics.

The perceived asymmetry of directed time with undirected space has generated a huge literature, the end of which is nowhere in sight. The universal expectation is that the unrestricted particle movement found in the space dimension should characterize that same particle "moving" in the time dimension. The flaw here is to ignore the fact that rest mass resides in (occupies) space; exchanging a time view for a space view of the rest mass doesn't alter that, it just means the exchange is necessarily flawed.

Swapping time for space must accompany swapping (photon) KE for rest mass (Sec. 2.1). When this is done, the inexorable advance of time for the inertial particle entity has its symmetric parallel in the inexorable advance (expansion) in space for the photon entity; and in both cases the rate of advance is the absolute maximum.[8] Of course, the time versus space asymmetry of rest mass is an idea that is attractive due its simplicity (Appendix A); it will not go away any time soon.

Many writers draw comparisons between the advance of time and the increase of entropy [6, Sec. 2]. Those who believe that time reversal is possible for isolated matter are left to explain why a law of thermodynamics indicates this cannot happen for matter in the aggregate. The connection between the two may be questioned; beyond that, time doesn't reverse either for matter individually or matter collectively.

Advancing in but one dimension, time or space, characterizes the inertial particle and the photon respectively; this is, or appears to be, part of the universal entity template. By confining physical reality to rest mass objects and their time advance, and by ignoring the photon which has no time advance at all, commentators manufacture asymmetry for the part (the particle) and overlook symmetry for the whole.

[8] Technically, it is the progressing potential identities of rest mass and photon KE that advance in time and space respectively. Essential identities reside in the orthogonal, non-progressing dimension making them always available for events located in both space and time. Entities are subtle; they merit study.

**10. The double slit and the Mach-Zehnder interferometer**

Photon behavior in the Mach-Zehnder interferometer (MZI) and in the double slit is still a mystery to us; experiments involving them continue, usually now using entangled photons.

**Double Slit**: Richard Feynman said that the double slit "…has in it the heart of quantum mechanics" and added that "…it contains the *only* mystery [7, 1-1]." The double slit is mysterious only if one regards, as Feynman did, the photon as a unitary object whose energy (as payload) navigates space. But with photon KE in time, only the photon's potential, waveform identity navigates the two slits with the resulting interference pattern only determining probable photon KE reception.

Assume a stream of phase-coherent photons are generated; their waveforms pass through the two slits and trigger multiple reception events on a screen. Each reception event location is individually random, but, in the aggregate, the reception events conform on the screen to the (probabilistic) waveform diffraction pattern of each and every (identical) photon.

The wave pattern of each photon is the same since the diffraction is deterministic. But individual photon (KE) reception on a screen requires an interaction event between opposing (mass, energy) entities residing in orthogonal dimensions (space, time); these interaction events can never be deterministic.

The conversion of photon KE to a reception event collapses the space-dispersed relativistic mass waves nonlocally since they are all dependent on an orthogonal occurrence (oscillation) in time; the waves cease to occur; they disappear without a trace.[9]

**Mach-Zehnder interferometer**: Photon probability-of-reception waves must progress in space to occur, just as rest mass must progress in time to exist. In general, if a portion of a photon's probability-of-reception wavefront is blocked by a material object and can't progress, the blocked waves either collapse without a trace or they initiate a reception event at a point on the object. If no reception event is initiated, the incorrect assumption is typically made that nothing was received by the blocking object.

Our physics (our ontology) cannot deal with probability waves that impinge, collapse and leave no trace on our material instruments. We believe that all real things (i.e., particles and the forces they carry) leave traces we can detect. In the MZI, the collapse and non-detection of probability waves leads to significant errors of interpretation.

When a single photon enters the beam splitter of a MZI, photon KE in time is unaffected while the probability-of-reception wavefront is divided into half intensity on the two paths. If the paths are not blocked, the two waves reunite at the second beam splitter and interfere "proving" the photon is a wave.

If one of the MZI paths is blocked and if the photon KE is received (at a point, of course) on that barrier, the conclusion drawn is that the photon as a "particle" chose that path over the other path. The flawed logic then becomes: 1) blocked path(s) "make" the photon choose one path or the other as a "particle"; and 2) unblocked paths "make" the photon travel both paths as a wave.

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[9] The common locution is to say the waves "cease to exist" which is incorrect. The waves do not exist in the first place since they are neither material, nor quiescent nor do they constitute a state or a condition. We conflate "to exist" with "be real" because our ontology is mass-centric forcing energy to borrow its nomenclature. Rest mass particles exist; photons occur; both are physically real and both use space and time to function, i.e., to reside and to progress.

From this John Wheeler argued (echoing his mentor Bohr) that the nature of reality – particle versus wave – depends upon what questions we ask of it; that is, on what experimental, measurement configuration we employ.[10] He assumed that the (unitary) photon made a particle/wave "choice" at the first beam splitter. He also assumed that this choice might depend upon the configuration of the MZI: paths blocked or unblocked. Perhaps, he thought, the photon might be forced to revise its choice (retroactivity) if blockage was added or removed after the photon left the first beam splitter. This led him to suggest his famous "delayed choice experiment [9]," the tests of which, and confusion over, have continued to this day. The crux of this imbroglio is the photon regarded as unitary, in space and being both discrete and continuous.

## 11. The speed of light

Relativity theorists love to treat space and time as a unity, namely spacetime, that may be, for human convenience only, partitioned on a sliding scale into more or less of one versus the other [10]. But in terms of their role in facilitating events, space and time are orthogonal just as they are portrayed on a Minkowski diagram of events.

It is this orthogonality, plus $E = mc^2$, that enables something occurring in time to sustain (borrowing from above) "…space-progressing waves [that] are immaterial, occurring… dependencies of oscillatory photon KE."

These oscillatory, potential, probability waves – in synch with EM oscillations – constitute the space presence of the in-flight photon. As pure waves, their advance in space is a function of their cycle wavelength times their cycle frequency; this is their phase velocity. An observer moving toward the photon source measures a shorter wavelength but higher frequency (blue shift). As the observer moves away from the photon source the wavelength is now longer but the frequency is reduced (red shift). The phase velocity of light (in a vacuum) never changes regardless of observer motion. The speed of light for all observers is really the speed of immaterial EM and probability waves, not of photon energy. And that speed is simply a constant phase velocity.

For Einstein, pondering the nature of light in 1905, diffraction and Maxwell's equations ruled out the particle model; and the constant speed of light ruled out the ether as a medium. And so, as Einstein described it years later to his biographer [11, pp.51-52]:

> "I despaired of the possibility of discovering the true laws by means of constructive efforts based on known facts. The longer and the more despairingly I tried, the more I came to the conviction that only the discovery of a universal formal principle could lead us to assured results."

Einstein's principle approach, his second postulate – the constant speed of light – was not a discovery, it was an assertion. It was ignored or not regarded with favor in the early years; neither Planck and Lorenz approved of it and they had far more prestige than did Einstein who was just starting his career.

But no one else had a solution for the issue, and once Einstein achieved global renown for his general relativity theory, his second postulate acquired more respect. Soon it became accepted, featured in textbooks and passed on to successive generations. As was the case with Bohr's concept of dualism (complementarity), Einstein's postulate became a makeshift rationale that discouraged questioning by any physicist who wished to pursue a career within mainstream physics.

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[10] Einstein hated this approach to "reality." He wrote, "…the sore point lies less in the renunciation of causality than in the renunciation of a reality thought of as independent of observation." Quoted in [8, p.374]. Hence Einstein's rhetorical question, "is the moon only there when one looks at it?"

And that is where we stand today. We still think photon energy must travel space paths as a payload which should make it obey Galilean relativity. But it doesn't so we depend upon an ad hoc postulate to exempt the issue from inquiry and we move on.

## 12. Nonlocality

Photon nonlocality is the current great, inexplicable mystery of physics; one that has yet to acquire a makeshift explanation. It allegedly demonstrates, according to every pop science writer, the refutation of realism plus our inability to understand Nature and especially QM. Nonlocality depends upon entanglement which is actually common to all entities, existing or occurring. It is one more example of the invariant behavior of equivalent entities: particles and photons.

Entanglement is the bonding of like entities in a dimension they share (reside in): two photons bonding their kinetic energies together in time, or two particles bonding their rest masses together in space. Once again, to recognize invariant bonding you have to exchange both the entities and the dimensions in which they bond/reside. Atoms may have a rest mass bonding if they are adjacent in space; photons may have a KE bonding if they are adjacent in time. Photon kinetic energies are time adjacent if they are the product of the same event.

Assume that a stream of photon probability waves enters a nonlinear crystal. These wave oscillations are the potential side of photon KE and occasionally they induce – via spontaneous down-conversion – a splitting of the photon KE that sustains them. Two lesser-energy photons are the result with their energy oscillations bonded (entangled) in time and their merged, yet frequency-distinct, probability-of-reception waves expanding in space. A single, high-energy photon with two identities becomes two lesser photons each with two identities.

The two probability-of-reception waves of the daughter photons head off in space to widely separated rest mass detectors A and B. To simplify things, assume the space paths of the entangled photons are constrained to different fiber optic cables terminating at A and B. Observer A receives her photon as spin up; observer B receives his photon 100 nanoseconds later as spin down; as a pair they are always anti-correlated.

Observers A and B know their space separation and calculate that no speed-of-light signal can leave A and get to B in 100 nanoseconds. They conclude that spin coordination is over space from A to B and is instantaneous, a violation of Einstein locality. They are (unconsciously) assuming that it is photon energy that traverses each fiber optics cable as a packet or payload. Instead, the two entangled photon energies (as entities) remain bonded in time until the energy of one undergoes a transfer event to a material target; this event triggers spin definition for the pair. The space separation of the reception events for the two photons is of no consequence since spin coordination takes place in time once the KE of the first photon begins a target reception event. It is photon potential identities that traverse the two cables, just as they traverse the two arms of the MZI (Sec. 10. above).

The prevailing interpretation of photon nonlocality invokes particle mechanics by imagining photon objects as particles/payloads navigating space and therefore residing (being present) in it. Commentors never question this assumption, nor do they incorporate the wave nature of the photon since the concept of dualism allows, even encourages, one to select the photon model – wave or particle – convenient for the circumstance.

Photon entanglement is the sharing of KE between quantized objects. Such energy sharing can also occur between electrons: 1) those that are spatially adjacent and synchronize their oscillations (energies); or 2) those that have received energy from entangled photons. But photon KE sharing via entanglement remains the most puzzling because of the distances over which coordination appears to take place. Photon entanglement constitutes one more instance where modern physics has pushed theorizing and experimentation to the limit without having resolved fundamental issues and paradoxes. In this case the theorizing and experimentation proceed with: 1) no adequate model of the photon; and 2) no questioning of the applicability of particle mechanics to massless radiation.

Einstein instinctively knew that nonlocality was wrong; that there is no instantaneous action at a distance. Most current pop science writers use Einstein's position on nonlocality as an example of where he went wrong, of where a genius can stumble. It turns out Einstein was correct after all and he didn't stumble; there is no spooky action at a distance. And realism is not refuted.

## 13. Summation

Special relativity has given us a set of opposing equalities – mass with energy and space with time – that, in theory, allow for their transformation (swapping) because the equivalence of opposites implies an inversion of entities and dimensions. That inversion theory is tested here by comparing the invariant features of particle and space with photon and time (Sec. 4.).

The inertial particle as both stationary in space and residing there leads one, by a symmetry of inversion, to photon KE as both stationary in time and residing there. Putting the photon's energy in time as one identity while its other identity, probability-of-reception waves, advances in space cuts the Gordian knot of dualism by permitting one identity to exhibit the discrete (as a point reception *event*) and the other to exhibit the continuous (as rarefying waves). Reasonable explanations then emerge for the role of space and time for all entities; the arrow of time, the double slit, the Mach-Zehnder interferometer, the constant speed of light and nonlocality.

It may seem eccentric, to be charitable, to resolve all these issues at a stroke. On the other hand, once you stop forcing massy particle mechanics on to massless radiation, and once you start recognizing the foundational symmetry special relativity provides, many ripe fruits fall into your hands.

The preceding has been confined to inertial, which is to say space-stationary, rest mass; a topic of no interest whatsoever to any physicist; no mathematics save for boring stress and strain calculations. Whereas the inertial particle and the photon are "pure" entities by virtue of not mixing rest mass with KE, matter-in-motion is a "mixed" entity; i.e., a combining of the two. The result is a blending of opposing characteristics in the one dimension wherein our instruments actually operate (space). For the always-moving electron as a mixed entity, it has: 1) a particle-like trajectory, albeit a fuzzy, wave-like one; and 2) a probabilistic (de Broglie) waveform, albeit localized around the rest mass. The electron is a particle compromised by a waveform and a waveform compromised (packetized) by a certain space locus. The result is uncertain (particle) position and uncertain (matter wave) momentum. In addition, the photon's probability wave collapse upon reception has its counterpart in the electron's probability wave function collapse upon measurement. But all this is covered elsewhere [12, Sec. 8 - 13].

For all of the claimed advantages of the above, it is unfortunate that no one, you possibly excepted, will believe any of this and the reasons are not hard to find.

First, we are creatures of massy objects in space; that is our reality and always will be; radiation and photons are abstractions and we shall model them after what we know (particles and payloads) from our experience.

Second, words on paper and pixels on a screen don't convince anyone. Decisive experiments do, but that doesn't seem possible because we are now dealing with a realm (time) that our space-material instruments cannot penetrate.

And finally, people, including physicists, don't like to change their long-held ideas. There is the personal and institutional investment in the current (makeshift) theory of radiation. Its defects are now accepted as "features" not in need of explanation; a situation so similar to the many "correct" physics paradigms of the past that required their own makeshift justifications.

Despite these obstacles all is not lost. There are physicists and thinkers who continue to question orthodox opinion,[11] just as Einstein and Bell did. And, unlike an earlier generation, current thinkers are mostly free from the naïve "solutions" the Copenhagen school advanced. Unfortunately, for most of them energy and its equality with mass are mostly ignored and reality is still framed in terms of the universality of particles moving in space.

But we are still at the early stages of understanding QM and if settled practitioners are disposed to "cling tenaciously to what they…think they know,"[12] namely makeshift explanations (plus an ad hoc postulate), newcomers with the natural rebelliousness of youth may be more skeptical. One can only hope.

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[11] An incomplete list includes: Lee Smolin, Adam Becker, Jim Baggott, Sabine Hossenfelder and David Lindley

[12] Abraham Pais: "Like the rest of humanity, physicists tend to cling tenaciously to what they know or think they know, and give up traditional thinking only under extreme duress. [13, p.137]."

# Appendix A

## Simple Ideas and Physics

People love simple ideas. They embrace them so eagerly that proof becomes quite unnecessary; witness the popularity of groundless conspiracy theories; or the oft-heard mantra "everything happens for a reason."

Physicists are people and they too love simple ideas. Many ideas/concepts in physics are simple because they are derived from our experiences. Some have already been described. Energy as a quantitative payload is a simple idea as is using particle impact to explain the point reception of an object, the photon, that has neither rest mass nor particle characteristics. Both ideas are without proof but are regarded as not needing it; their simplicity makes them self-evident.

Detailing simple ideas over the history of physics is too easy; there are so many instances in the last century, QFT being one example. Imagining an infinite field in space supporting every possible present and future particle is a simple idea. It might even be true; we don't know for sure since mathematical success still leaves ontology underdetermined. Other examples come courtesy of Niels Bohr and his disciple, John Wheeler, as both were in love with simple ideas; their gifts to us include: complementarity plus yin/yang; participatory universe; it from bit; retrocausality; and one-electron universe. Simple ideas that are surely wrong (and silly), but with a certain following nevertheless, include the wave function of the universe and the many worlds theory (with multiple copies of you and I); the latter having an early imprimatur from John Wheeler. Their appealing simplicity trumps the lack of proof for either one.

Simple ideas/theories in physics are not necessarily wrong. But if you look at the history of physics, most of them are. Aside from extrapolating from common experience, simple ideas are often wrong because their explanation is constructed for a single issue/problem; they are ad hoc. That characterizes most current explanations of QM and the measurement problem.

Some physical ideas are simple and important, but they escape our attention and, lacking mathematical formulation, they don't qualify as physics. Two examples are: 1) entities don't have a defined location in the dimension where they do not reside (your desk has no defined time location); and 2) photon reception has a defined location in both space and time but as an event, not as an entity. This confusion between entity location and event location is pretty much universal.

Einstein thought a lot about theories in physics and came to two conclusions. First, he argued that a correct theory is one that addresses many problems: gestaltic verification. Second, he opted for refined and ingenious over simplistic when he stated that God (Nature) is subtle. Consciously or not, I have tried to follow Einstein's advice.

Symmetry is a very simple idea and most modern applications of it have been fairly pedestrian. The symmetry I have proposed – between inverted opposites, inertial particle and photon – has never been considered, much less explored. The invariants this symmetry yields are "subtle" in the sense of characterizing all entities but at an abstract level. These invariants (shared characteristics) are not limited to, but include: quantization; dual identities; entanglement in the residing dimension; and common utilization of dimensions (residing versus progressing). This approach is unfamiliar and will no doubt meet with some hostility. But I don't see how one can dispute the physics involved if one is willing to take seriously the equalities that special relativity gives us: mass with energy; space with time.

The real value of the invariants I have identified lies in what they tell us about the photon, namely, that, just like the inertial particle, it is an entity with two identities each with different functionality in two dimensions. This unification is also subtle: Nature has but one template for entities, with mass as the basis for an existing version (in space), and energy as the basis for an occurring version (in time).

Separating particle physics (matter-in-motion) from radiation, getting rid of the "photon payload" concept and putting KE in time fulfills the other Einstein requirement, gestaltic verification. New interpretations (explanations if you will) emerge for: dualism; photon point reception; the arrow of time; the double slit; the MZI; the constant speed of light; and nonlocality. Frankly, that exceeded my expectations and, perversely, solving too many problems just might work against me; so be it.

I have covered a lot and not without mistakes, but at least by starting with primitives – mass, energy, space and time – my analysis cannot be labeled ad hoc.

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