# The Concept of Mass as Interfering Photons

D.T. Froedge

Formerly Auburn University
*Phys-dtfroedge@glasgow-ky.com*

V032615

## Abstract

For most purposes in physics the concept of mass particles and photons are treated as though they are completely separate and distinct entities having little connection accept through collision interactions. This paper explores the concept of a mass particle being viewed as a pair of trapped photons in a mass-less box demonstrating proper relativistic dynamics and, Lorentz covariance. The mechanism of trapping of the photons in a particle is not herein defined and not important to the discussion since it is not required by the mechanics or mathematics that they be connected. Although this presentation is more relatable to a simple particle such as an electron, the dynamics must be the same for all mass particles with primary constituents that have phase velocities equal to c. This illustrates the concept of the equivalence of mass and energy, and why mass velocity cannot exceed the speed of light..

## Introduction

This paper was originally a demonstration of the connection, or comparison of the dynamics between a pair of trapped photons in a massless box, and a massive particle. With the realization that a gradient in c can induce not only the well known photon trajectories but also the proper dynamical properties of a mass defined as trapped photons, it has taken on, a greater degree of interest.[8]. If gravitation is merely a gradient in c that can be induced by QFT effects of path integrals, the mystery may be a little less obscure.

The special theory of relative, through the Lorentz transformations, yields the energy velocity relation for photons and particles, one through a shift in frequency, the other through a shift in mass. Considering these particles as different forms of energy, bestows a distinction between the forms of energy that is possibly unwarranted. The Lorentz transforms applied to a pair of photons can be shown to yield the same results as the transforms applied to a mass particle.

## Physical Model Appearance

The mechanism of containment of the light speed constituents need not be addressed for the purpose of this paper, nothing really requires it. The mathematical mechanisms are the same whether the photons are confined or not, and posing a massless box or stationary mirrors that contains the particles is as good as any other physical mechanism for the purposes here. If a photon is absorbed by an atom, there is an increase in mass equivalent to the energy of the photon. If an apparatus has a pair of parallel mirrors that trap photons the overall apparatus has an increase in mass, when they trap photons, thus there should be no issue as to whether two confined opposite going photons constitute mass.

A presumed appearance for particle such as an electron modeled by a pair of trapped opposite photons is not exactly a pair bouncing back and forth. For the simple electron, in the rest frame it is more likely the particle is spherical, with a path defined by the Dirac matrix $\gamma_1\gamma_2\gamma_3$ along each axis.

The angular momentum any axis being $\frac{1}{2}\hbar$. If the particle is set in motion, and presuming a standing wave in the rest frame, the part of the cycle in the direction of motion will see a decreased in wavelength, and the phase against the velocity would see an increased wavelength.

Since the direction of an observer's velocity is arbitrary, the defining of what constitutes separation into the forward and backward photons from a continuous energy loop has to do with the fact that for each observer there are two states forward and backward, along the velocity vector that share the total energy of the particle. The proportion of the energy in each state determined by the Lorentz transforms. A photon would have only one such state.

Obviously complete photons are not the constituents of particles otherwise the particle would disintegrate. Presumably, however the constituents are light speed, such as leptons, quarks, gluons, etc,

## I Momentum

Consider a thought experiment, in which two photons are placed in a perfectly reflecting mass-less container. If the two photons are not aligned in the given frame, then there is some sub-light speed frame, in which the photons are aligned, and in opposite directions, as well as having equal energy and frequency. This frame is the rest frame for the center of mass of the container for the two photons.

Using the momentum for the photons to be:

$$\vec{P} = m\vec{c} = \left[\frac{h\nu}{c}\right]\frac{\vec{c}}{c} \ , \tag{1}$$

where we can designate an energy equivalent "mass " for the photon to be:

$$m = h\nu / c^2 \tag{2}$$

The momentum of the container with respect to a moving frame of reference with velocity v is then:

$$\vec{P} = \left(m_1 + m_2\right)\vec{v} \ . \tag{3}$$

From the perspective of the individual opposite-going photons the momentum is:

$$P = P_1 + P_2 = \frac{h\nu_1 - h\nu_2}{c} = \frac{h\Delta\nu}{c} = \frac{h}{\lambda_B} \ . \tag{4}$$

The wavelength of the difference in the frequency here, or the "beat" frequency, is just the simple deBroglie wavelength.

The total energy, which is the sum of the energy of the photons, and thus sum of the frequencies, yields the simple Compton wavelength:

$$\frac{E_1 + E_2}{c} = \frac{h\nu_1 + h\nu_2}{c} = \frac{h}{\lambda_C} \ . \tag{5}$$

Using the above noted designation for "mass" we can write for the total "mass":

$$m_T = \left(h\nu_1 + h\nu_2\right)/c^2 \ , \tag{6}$$

Defining a mass for photons is not a unique concept and has been used by others [4]

The momentum is then:

$$P = m_T v = \left(m_1 - m_2\right)c \ . \tag{7}$$

Solving for velocity:

$$\frac{v}{c} = \frac{(m_1 - m_2)}{(m_1 + m_2)}. \tag{8}$$

This is notably just the velocity for the center of mass for two opposite going photons.

Since for a particle:

$$m_0{}^2 = m^2\left[1 - \left(\frac{v}{c}\right)^2\right]. \tag{9}$$

Putting in $m_T$, and $v/c$ and solving gives:

$$m_0{}^2 = \ (m_1 + m_2)^2 - (m_1 - m_2)^2 \ = \ 4m_1m_2\,. \tag{10}$$

So the square of the rest mass of the particle is four times the product of the "mass" of the individual photons.

## II Doppler

The same result is found by the use of the relativistic Doppler shifts on the individual photons as the result of a change in the velocity same picture can be viewed from the standpoint of the Doppler shift, on the transformation of velocity coordinates for the two photons.

The relativistic Doppler shift of the photons from one velocity frame to another is:

$$\nu_1' = \nu_1\left[\frac{1 - \frac{v}{c}}{1 + \frac{v}{c}}\right]^{1/2} \qquad \nu_2' = \nu_2\left[\frac{1 + \frac{v}{c}}{1 - \frac{v}{c}}\right]^{1/2}, \tag{11}$$

or using the above noted conventions for energy equivalent mass:

$$m_1' = m_1\left[\frac{1 - \frac{v}{c}}{1 + \frac{v}{c}}\right]^{1/2} \qquad m_2' = m_2\left[\frac{1 + \frac{v}{c}}{1 - \frac{v}{c}}\right]^{1/2}, \tag{12}$$

Multiplying the two relations gives:

$$m_1' m_2' = m_1 m_2 = \text{constant}, \tag{13}$$

and simple math gets:

$$m_1 m_2 = \frac{(m_1 + m_2)^2 - (m_1 - m_2)^2}{4}, \tag{14}$$

and:

$$\left[1 - \left(\frac{v}{c}\right)^2\right] = \frac{4 m_1 m_2}{(m_1 + m_2)^2} = \frac{m_0^2}{m^2}, \tag{15}$$

which is the same as the above relation, found for conformance to relativistic kinematics, the model thus transforms properly.

## III Four Momentum

Another approach to illustrate the mechanics of such a particle can be done by defining the null four momentum of a pair of opposite going photons. Defining the photon mass as in Eq.(6), the null four-momentum of two photons with opposite going phase velocities in the geometric algebra matrix form is:

$$\vec{P_1} = m_1 \left( \gamma^k c_k + \gamma^0 c \right) \tag{16}$$

$$\vec{P_2} = m_2 \left( -\gamma^k c_k + \gamma^0 c \right) \tag{17}$$

The square of the sum of the two null vectors is:

$$(m_1 + m_2)^2 - (m_1 - m_2)^2 = 4 m_1 m_2 = {m_0}^2 \tag{18}$$

The magnitude of each of these null four-momentum is zero for covariance, and the sum of two such moments must be constant. Thus $m_0$ must be invariant fixed quantity associated with the pair of opposite going photons. If this is defined as a rest mass then it is easy to identify:

$$\left(m_1 + m_2\right)^2 = m_T\,, \tag{19}$$

as the total mass. Factoring the total mass from Eq.(18), gives:

$$\left(m_1 + m_2\right)^2 \left[1 - \frac{\left(m_1 - m_2\right)^2}{\left(m_1 + m_2\right)^2}\right] = {m_0}^2 \tag{20}$$

Noting that from Eq. (8),:

$$\frac{\left(m_1 - m_2\right)}{\left(m_1 + m_2\right)} \tag{21}$$

is the ratio of the velocity of each photon to the velocity of the center of mass.

$$\left(m_1 + m_2\right) v_c = \left(m_1 - m_2\right) c \tag{22}$$

This makes Eq.(20), the relativistic energy equation for a mass particle.

$$m^2 \left[1 - \frac{v^2}{c^2}\right] = {m_0}^2 \tag{23}$$

It can thus be asserted that two light speed photons, or other confined light speed, zero rest mass particles, have the property of a mass particle, with mass energy equivalent to the energy of the individual particles.

## V Gravitation

The paper [8] “Gravitation is a Gradient in the Velocity of Light” by the author, details the interaction of gravity with the two photon model showing that the Lorentz transform with a

gradient in c accelerates the two photon model exactly as does gravitation. The details are developed in [8] and not restated here.

## Conclusion

The concurring points of similarity of the opposite going photons in a massless box model and the particles are consistent with:

1) The deBroglie wavelength.
2) The Compton wavelength
3) The zero velocity rest mass
4) The total energy
5) Velocity transforms
6) Gravitation

All of the real internal constraints such as spin, energy, etc, which may be important to the actual mechanics of holding a particle together are not necessary to understand the concept.

Using a reflecting container is somewhat artificial, but the dynamics of the center of mass of two photons is the same whether the photons are confined or not, and the transformation of momentum between velocity frames, are not depend on the internal structure. The transformations and the mechanics for both the photon pair, and a massive particle are exactly the same, and it is easy to understand from this model why mass particles cannot exceed the speed of light.



References:

1. DT Froedge, Scalar Gravitational Theory with Variable Rest Mass ,V020914, http://www.arxdtf.org/css/grav2a.pdf

2. DT Froedge, The Velocity of Light in a Locally Conserved Gravitational Field, V101914, http://www.arxdtf.org/css/velocity.pdf

3. Roger Blandford, Kip S. Thorne, in Applications of Classical Physics, (in preparation, 2004), Chapter 26 http://www.pma.caltech.edu/Courses/ph136/yr2002/chap26/0226.1.pdf

4. Alex KruchkovBose-Einstein condensation of light in a cavity http://arxiv.org/pdf/1401.0520v2.pdf

5. D. Kharzeeva, K. Tuchinb, Vacuum Self–Focussing of Fery Intense Laser Beams, arXiv:hep-ph/0611133v2

6. Feynman, Hibbs, 1965, Quantum Mechanics and Path Integrals McGraw-Hill pp 24,

7. Chambers, R.G. (1960). "Shift of an Electron Interference Pattern by Enclosed Magnetic Flux". *Physical Review Letters* **5**: 3–5.Bibcode:1960PhRvL...5....3C (http://adsabs.harvard.edu/abs/1960PhRvL...5....3C)

8. DT Froedge,. Gravity is a Gradient in the velocity of light V031515, http://www.arxdtf.org/css/Gravitation.pdf