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Momentum and Energy of a Mass Consisting of Confined Photons and Resulting Quantum Mechanical Implications

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Abstract

A one-dimensional model is presented, in which a photon, confined in a cavity, represents a model of mass. Photon-particle-interaction is reduced to a free photon-confined photon interaction, for which changes in momentum are exclusively Doppler-based. The energy conservation itself describes a "storing" of the colliding free photon in the cavity. It fuses with the confined photon and decays in spontaneous or delayed fashion by emission of a Doppler-shifted free photon. Delayed emissions lead to a "stop-and-go" motion of the cavity in accordance with the quantum mechanic de Broglie relation between momentum and wavelength. This kind of motion consumes no energy and overcome potentials with minimum energy consumption. To simulate a massless cavity, the model requires the existence of a photon pool similar to the zero-point radiation described by Casimir (1948). This photon pool and a thermal fraction help to stabilize and conserve the cavity. Acceleration by means of a swarm of incident free photons at a cavity triggers a series of phase mismatches with the confined photons which lead to a distortion of the pool distribution. It is expected that an attractive "stop-and-go"-displacement of probe masses behind the accelerated cavity takes place – an effect consistent with energy conservation.

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1. Introduction

Currently world wide effort is focused on the questions of what is mass, how mass comes to elementary particles, and why masses move with velocities below the speed of light. Following a theory of Higgs [1] and others, the so called Higgs field gives elementary particles such as Z- und W-Bosons their mass. At the present time the search for a so-called Higgs particle coming from the Higgs field is continued at the Large Hadron Collider (LHC) in CERN. Of similar importance is the question of why the mass of a proton is larger by a factor of nearly hundred than the mass of the constituent quarks [2]. Obviously, the force that confines the quarks in the proton is accountable for this mass amplification effect. Following the Standard Model [3], the interaction of quarks happens via gluons in an exchange process. An interesting question is of course how these gluons generate mass [4]. The model which is presented here tries to follow up on this question and defines a mass for which particles that travel with the speed of light are confined in something which will be called cavity in the following. The cavity itself should of course be “massless”; the particles are proposed to be thermal photons with well known behavior in terms of momentum, energy and Doppler Effect.

In the proposed model, the thermal photons inside the „massless” cavity are continuously reflected back and forth with 180°-Compton collisions at mirror walls. Although photons move with the speed of light, if they are localized, or confined in a cavity, they behave as if they have mass (a fact already pointed out by Einstein [5] when he discussed the mass of heated matter). It can be demonstrated that confined photons gain momentum and kinetic energy in the same manner as an ordinary mass. Therefore, in the following the unit of thermal photons confined in a cavity will be called **photonic mass**. This model only works if space contributes a photon pool that causes a stabilizing counter-pressure to the confining cavity. Absorption and emission of free photons by localized confined photons allow insight into the mechanism of the conservation of energy and of the resulting quantum mechanical implications. All conclusions concerning momentum and energy rely on 1-dimensional relativistic calculations. This means that only perpendicular components of the wave propagation with respect to the cavity walls are considered. The situation of isotropically distributed propagation of the wave needs higher dimensionality in the description. The same is true with effects such as spin, polarization etc.. It is important to note that results based on this simple model may not describe reality in detail but may still give useful information. Since the Compton process as the standard collision process plays a dominant role, the description starts with the main features of collision physics.

2. Three fundamental equations describe the elastic Compton collision

During reflection processes of photons with charged particles the Compton shift appears i.e., the wavelength of interacting photons is shifted. It is the conclusion of several authors [6, 7, 8, 9] that these shifts are identical to Doppler shifts, that is, after the interaction a particle moves with the velocity $\beta' c = v'$ and the interacting photon, coming back from the particle, is Doppler-red-shifted with respect to the relative velocity β´c. This is demonstrated next for the case of an elastic 180° Compton collision:

With the dimensionless abbreviations $\alpha = h\nu / mc^2 = h/\lambda mc = \hbar k / mc$, $\gamma = 1\big/\sqrt{1-\beta^2}$ and for an initial velocity $\beta = 0$ of the charged particle with mass m, by means of mutual addition and subtraction the well known solutions of both equations:

Energy: $$\alpha + 1 = \alpha' + \gamma' \quad (1)$$

Momentum: $$\alpha + 0 = -\alpha' + \beta'\gamma' \quad (2)$$

are, where "prime" indicates the situation after the collision:

$$\alpha' = \frac{\alpha}{1+2\alpha} \quad (3)$$

$$\gamma' = 1 + \frac{2\alpha^2}{1+2\alpha} \quad (4)$$

The Doppler equation can be derived if Eq.1 and 2 are rewritten as:

$$\gamma' = \alpha - \alpha' + 1 \quad (5)$$

$$\beta'\gamma' = \alpha + \alpha' \quad (6)$$

Subtraction: $$\gamma' - \beta'\gamma' = 1 - 2\alpha' \quad (7)$$

Addition: $$\gamma' + \beta'\gamma' = 1 + 2\alpha \quad (8)$$

From the definition of γ one easily derives: $$\gamma - \beta\gamma = \frac{1}{\gamma + \beta\gamma} \quad (9)$$

Eq.7 and 8 result in:

$$\gamma' - \beta'\gamma' = 1 - 2\alpha' = \frac{1}{1+2\alpha}. \quad (10)$$

A comparison with Eq.3 gives:

$$\gamma' - \beta'\gamma' = \frac{\alpha'}{\alpha}, \quad (11)$$

which is the Doppler equation. This result suggests the following interpretation:

CONCLUSION 1. The Compton Effect can be understood as a two step event. The ***first step*** *is the reflection of the photon, when both mass and photon change from the laboratory system into the moving, colliding system. Then, in the* ***second step*** *the retransformation of the photon into the laboratory system takes place. In this step the Doppler red-shift as formulated in Eq.11 occurs.*

Since a change of photon energy is exclusively a result of Doppler shifts (see ref. 6-9), the Compton collision for these kinematics can be derived directly from momentum conservation and the Doppler shift:

Using $\gamma = 1/\sqrt{1-\beta^2}$ the Doppler equation $\alpha' = \alpha\gamma'(1-\beta')$ gives:

$$\beta' = \frac{\alpha^2 - \alpha'^2}{\alpha^2 + \alpha'^2} \quad \text{and} \quad \gamma' = \frac{\alpha^2 + \alpha'^2}{2\alpha\alpha'}. \tag{12}$$

Inserted into the momentum equation $\alpha + 0 = -\alpha' + \beta'\gamma'$ the solutions Eq.3 and 4 follow, without making direct use of energy conservation. The elastic Compton collision process seems to be reasonably described by momentum conservation and Doppler shift alone. It is easy to show that Doppler- and energy equations yield the same results; all combinations of two of the three fundamental equations describe the elastic Compton collision. Mathematically seen the Compton Effect is overdetermined. The question arises, how these equations relate to the others and why and does it matter?

To answer this, I propose a model in which the particle mass is generated by confined photons and that allows to simplify the photon-particle interaction into a photon-photon interaction. As mentioned, in this model of photonic mass the photons are confined in a cavity, reflect back and forth between two mirrors and create rest energy. Motions of the cavity imply simultaneously Doppler red and blue shifts of the confined photons, and in addition to the rest energy a kinetic energy term appears. Therefore a collision with a free photon eventually leads to Doppler shifts of all involved photons – no matter whether they are free or confined. This leads to the conclusion that energy conservation can be regarded as based on Doppler shifts, that is, energy conservation is a Doppler shift conservation. But this is only part of the truth. Energy conservation describes a fusion- and decay process between free photons and particles, that is, confined photons, that is, photonic mass (see Sect.7). This leads to a quantum mechanical behavior of these particles (see Sect.9)

To simulate realistic mass particles, the assumption of a massless cavity that is constructed from weightless mirrors must be introduced. Mechanical stabilization by rods, springs etc., leads to vibrations of the cavity, which cannot be observed for real particles (see Sect.3.1). To stabilize the geometric arrangement of the cavity mirrors (i.e. the mirror distance), a non-closed physical system is taken into account (see Sect.3.2). This calls for the cooperation of a surrounding photon radiation field similar to what Casimir [10] described as the zero-point radiation of space. The geometrical arrangement of mirrors and photons is the subject of the next Section.

3. Confined light in a cavity which is at rest or in uniform motion

During reflection at a mirror, propagating waves build up a standing wave pattern. In a cavity with two mirrors with perfect photon-reflecting capability, set up in parallel at a distance L, the spectrum of standing waves appears:

$$\lambda = \frac{2L}{n}, \qquad \text{where } n = 1, 2, ... \tag{13}$$

In principle, each of the standing waves with wave number n can be populated with an arbitrary number of confined photons.

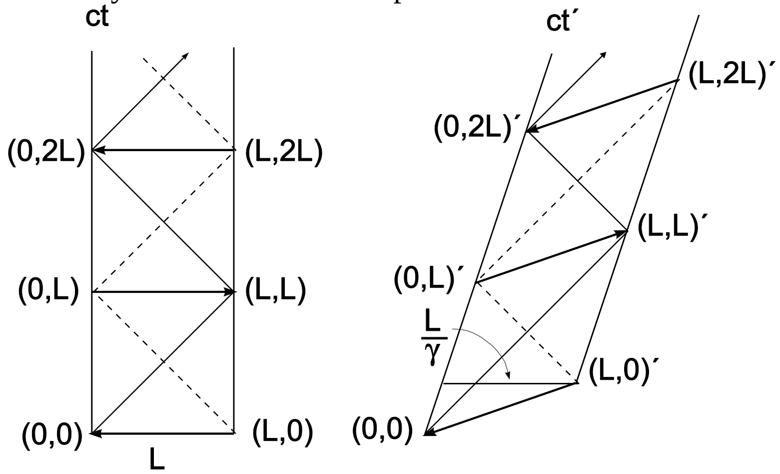

Fig.1: A cavity at rest and in motion in a space-time presentation where the 45°-lines represent the zigzag spread of a wave

Figure 1 shows a cavity at rest (left) and in motion (right) in a Minkowski space-time presentation. For the case n = 2L/λ =1, the 45°-lines show the zigzag spread of the wave front (solid line) and the wave end (dotted line). The thick arrows are connection lines between wave ends to fronts. In a system at rest they are denoted as „wavelength“. In a moving system they are slanted and 2-vectors (since the model is 1-dimensional).

The half wave moving to the right is blue- and the half wave moving to left is red-shifted since they reflect at the approaching and receding sides of the mirror, respectively.

On the basis of a common zero point, the expressions of the Lorentz transformation are

$$\begin{aligned} ct' &= \gamma\left(ct - \beta x\right) \\ x' &= \gamma\left(x - \beta ct\right) \end{aligned}, \tag{14}$$

here “prime” indicates a different reference system. In Fig.1, the observer moves to the left. Therefore β is negative. The transformed coordinates are:

$$(0,0)' = (0,0) \tag{15}$$

$$(L,0)' = (\gamma L,\ \beta\gamma L) \tag{16}$$

$$(0,L)' = (\beta\gamma L,\ \gamma L) \tag{17}$$

$$(L,L)' = [\gamma L(1+\beta),\ \gamma L(1+\beta)] \tag{18}$$

$$(0,nL)' = (n\beta\gamma L,\ n\gamma L) \tag{19}$$

$$(L,nL)' = [\gamma L(1+n\beta),\ \gamma L(n+\beta)] \tag{20}$$

The transformed distance between the mirrors which is related to the wavelength is a 2-vector. The corresponding space and time intervals of the wavelength are:

$$(L,0)' - (0,0)' = [\gamma L,\ \beta\gamma L] \tag{21}$$

$$(L,L)' - (0,L)' = [\gamma L,\ \beta\gamma L] \tag{22}$$

and so on. As can be seen in Fig.1, right graph, the length contraction of a moving cavity is L/γ, which is in agreement with standard relativistic models. To show this: The slope of the ct′ line in Fig.1 is $1/\beta$. Using Eq.16, a line through (L,0)′ with this slope intersects the line y = 0 at $x = \gamma L\left(1-\beta^2\right) = L/\gamma$.

3.1 Problems with the physics of a real cavity

In many regards, Fig.1 does not represent a realistic model for a “free” particle, constructed solely from confined photons located in a mirror system in a massless cavity. To give an example: Assume two photons with a phase difference of π in the cavity. At any time, the momentum transfer of the left-reflecting photons must be compensated exactly and instantaneously by the momentum transfer of right-reflecting photons to maintain the mirrors at rest. Massless mirror connection rods for momentum transfer are physically not available; instantaneous momentum transfer contradicts the finiteness of the speed of light. In addition, any mass-like rods lead to spacing vibrations between the mirrors and increase the internal energy. In this case, the energy balance for inelastic collisions should be:

$$\alpha + 1 = \alpha' + \delta' + \gamma' \tag{23}$$

where δ′ represents the vibration excitation. In photon-particle (i.e. electrons or protons) interactions the term δ′ is zero. Therefore in this model a pool photon scenario is chosen where external photons reflect simultaneously with confined photons to compensate the mirror momentum.

3.2 An external photon pool such as Casmir’s zero point radiation generates pressure at the cavity walls

The proposed mechanism to maintain the distance of the mirrors is an external photon pool, as illustrated in the Minkowski space-time presentation in Fig.2 (outside reflecting photons with arrows). Massless mirrors are placed in a standing wave field of pool photons and confined photons. Reflections take place simultaneously at the inside and outside of a mirror, so that both mirrors remain at rest or in uniform motion – a process which is proposed to be called in-phase.

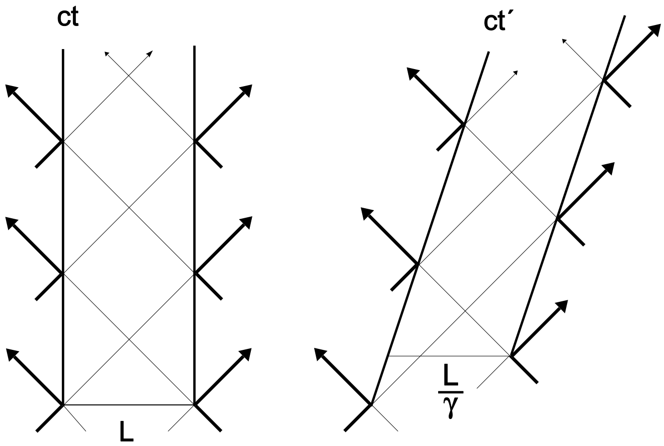

Fig.2: Space-time frame of simultaneous reflections of confined photons with external photons (thick arrows) for the cases of a cavity at rest (left) and in motion (to the right). This process will be called in-phase.

If a cavity is at rest, one would observe that confined photons $\hbar k^*$ and pool photons $\hbar k^p$ reflect instantaneously without Doppler shift, as shown in Fig.3 (left). If the cavity or the observer moves, all photons which interact with the cavity mirrors undergo red and blue shifts, as shown in Fig.3 (right). In this graph the abbreviations

$$D = \gamma(1-\beta) \text{ and } \frac{1}{D} = \gamma(1+\beta) \qquad (24)$$

describe the red and blue shifts of pool- and confined photons in a moving cavity, where the form of the blue shift in Eq.24 can easily be derived using Eq.9.

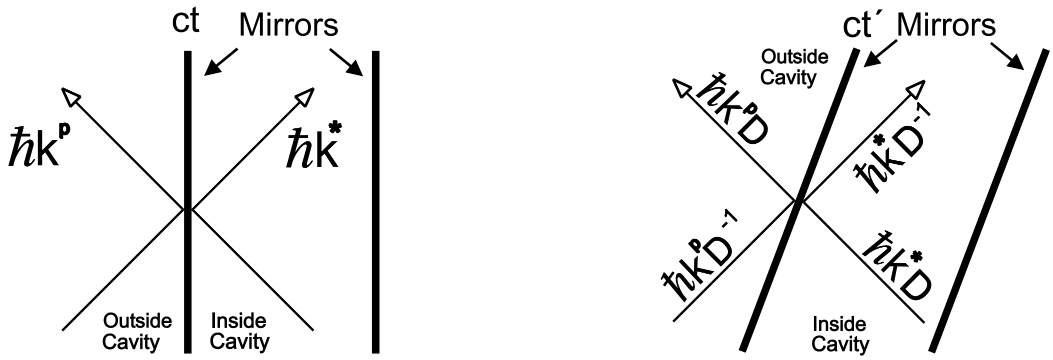

Fig.3: Space-time presentation of confined and pool photon reflections at cavity mirrors at rest (left) and in motion (right). Since photon momenta transferred to the mirrors are equal, the mirrors remain at rest or in constant motion after reflection.

The path of the blue-shifted confined photon $\hbar k^* D^{-1}$ is obviously longer than the red-shifted one $\hbar k^* D$, an outcome that is unexpected. This issue will be investigated in the next Section.

3.3 A standing wave in a moving reference system remains a standing wave

At first glance, the presence of a standing wave between a pair of moving mirrors (see Fig.1) seems to be impossible because the wavelengths of red- and blue shifted waves are not the same. However, relativity theory contradicts this, as will be demonstrated next:

A standing wave in a cavity is equivalent to a standing wave in front of a mirror at rest. During the reflection of a wavetrain, one wave moves toward and the other moves away from the mirror:

$$F(x-ct) = e^{i\omega(t-x/c)} \tag{25}$$

$$F(-x-ct) = e^{i\omega(t+x/c)} \tag{26}$$

Superposition of both waves gives (reflection at a mirror):

$$y = F(x-ct) - F(-x-ct) = e^{i\omega(t-x/c)} - e^{i\omega(t+x/c)} = e^{i\omega t} e^{-i\omega x/c} - e^{i\omega t} e^{i\omega x/c} = \\ = e^{i\omega t}\left(e^{-i\omega x/c} - e^{i\omega x/c}\right) = -2ie^{i\omega t}\sin(\omega x/c) \tag{27}$$

which results in a standing wave. In the case of a moving mirror the Lorentz transformation:

$$\begin{aligned} x' &= \gamma(x-\beta ct) \\ ct' &= \gamma(ct-\beta x) \end{aligned} \tag{28}$$

gives:

$$F'(x-ct) = F(x'-ct') = e^{i\omega/c\cdot\gamma(1+\beta)(ct-x)} = e^{\frac{i\omega}{cD}(ct-x)} \quad \textit{blue shifted wave}$$

$$F'(-x-ct) = F(-x'-ct') = e^{i\omega/c\cdot\gamma(1-\beta)(ct+x)} = e^{\frac{i\omega}{c}D(ct+x)} \quad \textit{red shifted wave}$$

The superposition y´:

$$y' = F(x'-ct') - F(-x'-ct')$$

$$y' = e^{i\omega/c\cdot\gamma(1+\beta)(ct-x)} - e^{i\omega/c\cdot\gamma(1-\beta)(ct+x)}$$

$$y' = -e^{i\omega/c\,\gamma(ct-\beta x)}\, 2i\sin\{\omega/c\,\gamma(x-\beta ct)\} = -e^{i\omega t'}\, 2i\sin\left\{\frac{\omega}{c}x'\right\} \tag{29}$$

that is the expression for a standing wave in a moving reference system.

A standing wave in a moving reference frame remains a standing wave, even though photons are Doppler shifted. Red and blue shifts do not imply a phase mismatch of the standing wave in a cavity, although the wavelengths differ. Such conclusions will not appear if the real and imaginary parts of the wave are considered in the calculation. This result is also in agreement with the well known invariance of the wave number as well as with the invariance of the phase in Special Relativity [11].

In contrast to the behavior of free photons, confined photons in a standing wave in a moving reference frame undergo length contraction (transverse Doppler Effect) and time dilation just like moving masses.

The overall momentum and the Doppler situation in the pool remain unchanged for a moving cavity. Reflected, Doppler-shifted pool photons such as $\hbar k^p D$ (see in Fig.3, right) have the same momentum as if they approach from the opposite side and penetrate the cavity ($\hbar k^* D$ represents this). Locally, it looks like a transfer from the pool- into confined photons and then as a transfer back into pool photons:

$$\begin{aligned} &\hbar k^p D_{left} \leftarrow \hbar k^* D \leftarrow \hbar k^p D_{right} \\ &\hbar k^p D_{left}^{-1} \rightarrow \hbar k^* D^{-1} \rightarrow \hbar k^p D_{right}^{-1} \end{aligned} \tag{30}$$

Equations 30 also give a proof that the neutrality of the pool distribution is not disturbed by the presence of a cavity, whether it is at rest or in uniform motion.

3.4 A photon pool consisting of Casmir's zero point radiation and an additional thermal component

At a first glance, the demands on the quality of space, as sketched above, seems to be unrealistic. But in the field of quantum electrodynamics, Casimir and Polder predicted properties of zero-point radiation in space that may fulfill such requirements [12]. Space is filled with electromagnetic zero-point radiation of nearly unlimited energy. Electrical conducting plates as shown in Fig.4 positioned at a distance L experience apparent attractive forces. They result from the fact that inside the cavity standing waves are established with $\lambda = 2\text{L}, \text{L}, \frac{2}{3}\text{L}, \frac{1}{2}\text{L}...$ Outside an additional pattern of standing waves with $\lambda = 4\text{L}, 6\text{L}, 8\text{L}....$ up to the diameter of space is present. Therefore, the flux of photons outside the plates is larger than inside the cavity. For the pressure P, Casmir's computation gives:

$$P = \hbar c \frac{\pi^2}{240 L^4} \quad . \tag{31}$$

It has been possible to measure the so-called Casimir force at metallic foils positioned at a distance of a few micrometers [13]. It should be mentioned that the distribution of wavelengths follows a cubic distribution that has an identical shape in any relativistic system [14]. Therefore, relativity is not affected in this standing-wave framework.

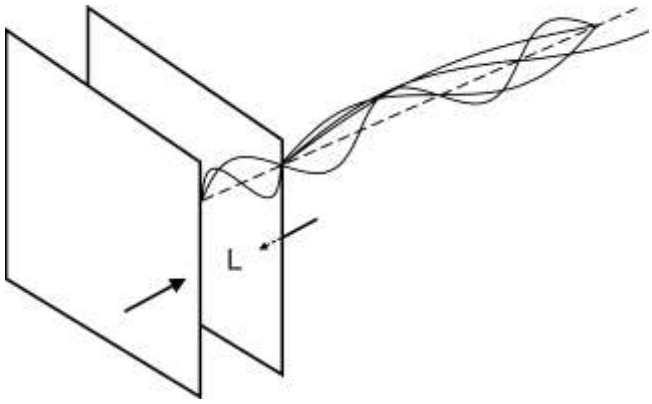

Fig. 4: Conducting plates at a distance L, where the number of modes inside is smaller than outside with the consequence that the outside long wavelength modes (i.e., $\lambda = 4L$) generate an inwardly directed force on the plates.

A cavity embedded in zero-point radiation will experience an overshooting outer pressure coming from the long wavelength spectrum. The pressure on the outside may be balanced by reflecting confined thermal photons on the inside. For instance, the pressure P_{confined} of n confined photons in a gap with a width of L, a wavelength $\lambda = 2L$ and a nonrelativistic momentum transfer of $2 \cdot \frac{2\pi\hbar}{\lambda}$ during reflection, acting on an area of about L^2 is:

$$P_{confined} = \pi n \frac{\hbar c}{L^2} \frac{1}{L^2} \tag{32}$$

A comparison with Eq.31 shows that the pressure described in equation Eq.32 is approximately a factor of $240 \cdot n / \pi$ larger; that is, an expansion of the cavity would take place. In addition to the zero point radiation, an outside acting thermal radiation is needed to balance the force acting on the cavity i.e., the photon pressure acting on both sides of each mirror is the same and the gap distance remains constant at L:

$$\hbar c \frac{\pi^2}{240 L^4} + \pi n \frac{\hbar c}{L^4}\left(1 - \frac{\pi}{240 n}\right) = \pi n \frac{\hbar c}{L^4} \tag{33}$$

A stabilizing thermal fraction (second term in Eq.33) is required. A spectrum of ultralong wavelength photons with wavelengths up to $10^{25} m$ (dimension of space) could represent the required thermal fraction. This isotropic long wavelength spectrum plays a decisive role in a theory of mass attraction governed by scattering and screening of photons as a new model of gravitation [15] (in this model a thermalization via the photoelectric effect seems suppressed since the oscillation time of a photon with $\lambda = 10^{25} m$ is several billion years). If this is true, a unified theory between photonic mass and gravitation may be within reach (see Sect.14 Outlook).

In principle, the number n of confined thermal photons in the cavity can be unlimited. This is also true with higher modes $\frac{k^*}{2\pi} = \frac{j}{2L}, with\ j = 1,2,3,....$and so on. However, on the basis of a given density of thermal pool photons (Eq.33, second term), the cavity will expand in a spacing between the mirrors proportional to L^4 (see Eq.32) to reduce the expansion pressure.

3.5 Mass of confined photons in a cavity

The number n of confined thermal photons existing in a massless cavity at rest represents a mass m^* with $n/2$ photons propagating to the left and $n/2$ photons propagating to the right:

$$m^* c = n\hbar k^* = \tfrac{1}{2} n\hbar k^*_{left} + \tfrac{1}{2} n\hbar k^*_{right}\ , \qquad (34)$$

In the simplest case, k^* is the wave vector with the magnitude $\frac{k^*}{2\pi} = \frac{1}{2L}$. In this case, the photons builds a standing wave pattern with synchronous right- and left-propagating half waves. As mentioned above, the number of confined photons n can have values $n = 1, 2$ and so on. The mass of the cavity at rest increases proportionally to the number n of confined photons. Of course, a proportional increase of mass will also take place with higher modes of a confined photon $\frac{k^*}{2\pi} = \frac{j}{2L}\ with\ j = 1,2,3,.....$

4. Behavior of a photonic mass versus a classical mass

We now discuss the momentum of confined photons in a moving cavity: In Fig.3 (right) one can see that confined photons in a moving cavity are Doppler-shifted. The cavity walls remain in uniform motion and the mirror distance remains constant but is contracted by the γ-factor. A confined photon in a moving cavity with mass m has the momentum $\frac{\hbar k^*}{D}$ when propagating parallel and $\hbar k^* D$ when propagating antiparallel to the cavity's direction of motion. Since in the derivation of Eq.25-29, the behavior of a standing wave is conserved when the cavity is in motion, the averaged magnitude of the momenta of the confined photons (in the ground state i.e., $\frac{k*}{2\pi} = \frac{1}{2L}$) is increased and can be written using Eq.24 as:

$$\frac{n}{2}\frac{\hbar k^*}{D} + \frac{n}{2}\hbar k^* D = \frac{n}{2}\hbar k^* \left(D + \frac{1}{D}\right) = n\hbar k^* \gamma = \gamma m^* c\ , \qquad (35)$$

The *averaged magnitude of the momenta* of a photonic mass is of course related to the kinetic energy. Equation 35 shows that the mass of a "photonic mass" increases in the same manner as an ordinary mass. The physical meaning of the momentum m^*c is, if all confined thermal photons $\sum_n \hbar k^*$ escape in one direction, the resulting recoil momentum of the escaped photons is m^*c. In analogy to Eq.35, the resulting momentum of confined thermal photons gives the resulting momentum of the photonic mass:

$$\frac{n}{2}\frac{\hbar k^*}{D} - \frac{n}{2}\hbar k^* D = \frac{n}{2}\hbar k^*\left(\frac{1}{D} - D\right) = n\beta\gamma\hbar k^* = \beta\gamma m^* c \quad (36)$$

As can be seen in Eqs.35 and 36, the terms on the right, such as kinetic energy and momentum, relate to an ordinary mass and the terms on the left relate to corresponding Doppler shifts of counter-propagating, confined thermal photons in a photonic mass:

$$\frac{1}{D} + D = 2\gamma \quad (37)$$

$$\frac{1}{D} - D = 2\beta\gamma \quad (38)$$

Equations 37 and 38 have the form of ordinary mass – photonic mass equivalence equations.

5. Principal considerations for a velocity change of a photonic mass

Let a free photon with wave vector k collide with a cavity or with a photonic mass at rest. This is a situation that can be described by a 180° Compton collision, but details where the free photon collides is the subject of Sect.7. After the collision, the cavity recoils. If one lets further free photons collide with a moving cavity, during a subsequent time interval then a model of mass acceleration is created. Of course, the acceleration is not continuous but stepwise. In QED “fields” and “forces” are produced by a charge via exchange of virtual photons with other charges. The presented model considers velocity changes of particles as a result of photon collisions.

As can be seen from Fig.5, a transition of a cavity from rest to motion represents a change in the spacing between the mirrors from L to $L' = L/\gamma$. A simple connection framework is shown in Fig.5.

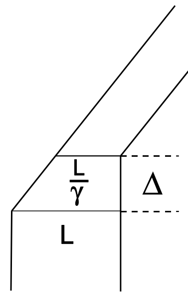

Fig.5: The free photon collision leads to a discontinuous transition of a cavity at rest into one in motion

This framework illustrates that after the front mirror starts to move, the opposite rear side of the cavity starts moving with a delay Δ. It resembles slightly the deformation of a kicked ball. The path of the colliding free photon has not been included, since the following investigations show that neither the kick at the front nor the one at the rear side is the location at which the reflection takes place. Nevertheless, the "kick model" is the simplest description of the envelope of a particle.

By means of elementary geometry, the transition time $ct = \Delta$ is found to be:

$$\Delta = \frac{\gamma - 1}{\beta\gamma} L \tag{39}$$

However a critical point is synchronization between the external collision of the Compton photon and the internal collisions of the confined photons without destroying the standing wave scenario. We assume propagating and counter-propagating photons with a phase correlation π as shown in Fig.6 and a sudden inclination as shown in Fig.5.

Generally the introduction of the confined photons into the inclined tube changes the phase relation, except for a special configuration as shown in Fig.6 (left) that conserves the phase relation π. In this case the front mirror starts to move with the delay t_x after the last reflection of the confined photon at this mirror.

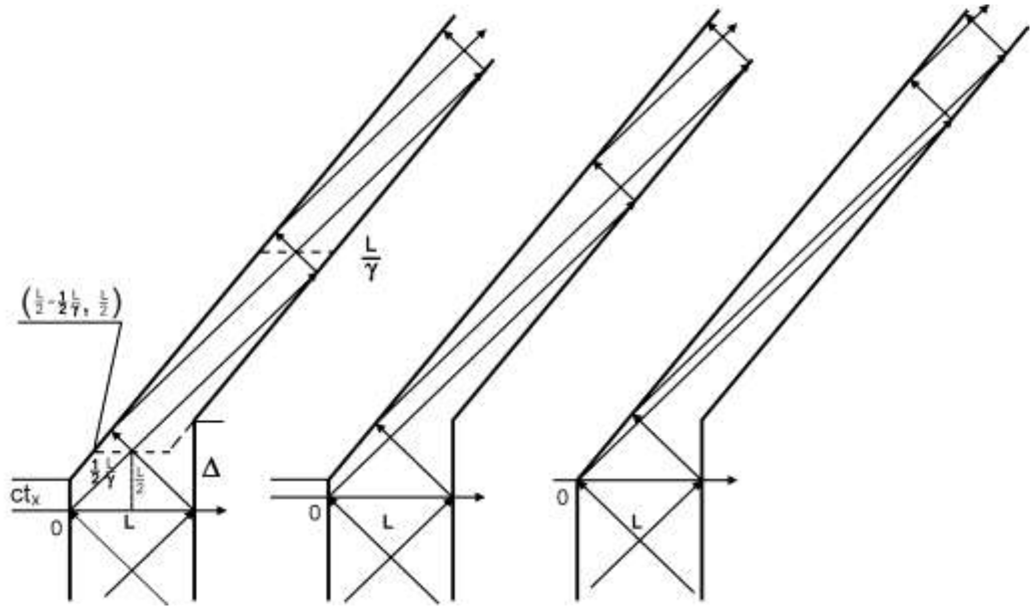

Fig.6: Three examples how a confined photon (standing wave situation) transits from a cavity at rest into a cavity in motion. Only the example on the left gives the phase conservation correctly.

The line through $\left(\frac{L}{2}-\frac{1}{2}\frac{L}{\gamma}, \frac{L}{2}\right)$ with the slope $\frac{1}{\beta}$ crosses the vertical line $x=0$ at the position ct_x:

$$ct_x = \frac{L}{2}\left(1-\frac{\gamma-1}{\beta\gamma}\right) \tag{40}$$

The following conclusions can be drawn from this framework: Only by chance will a free photon collide with the cavity in the right phase with respect to the phase of the confined photon. Most transitions do not allow a collision. A way out is to assume that at a collision confined photons are exchanged with pool photons from Casmir's zero-point radiation with correct momentum and correct phase relation. Before pursuing this further in Sect.10, a more detailed understanding of the Compton Effect in the context of a photonic mass i.e. a mass that results from a thermal photon confined in a massless cavity must be sought.

6. Compton collision of a free photon with a photonic mass

The conservation of energy and momentum in a Compton collision (Eq.1 and 2) can be rewritten for a "so-called" photonic mass. The confined thermal photons are divided into right- and left-propagating components. Energy and momentum have the form:

$$\begin{aligned} \alpha + \frac{n}{2} + \frac{n}{2} &= \alpha D' + \frac{n}{2}\frac{1}{D'} + \frac{n}{2}D' \\ \alpha + \frac{n}{2} - \frac{n}{2} &= -\alpha D' + \frac{n}{2}\frac{1}{D'} - \frac{n}{2}D' \end{aligned} , \tag{41}$$

A comparison of Eq.1 with Eq.2 with Eq.41 shows that n – the number of confined thermal photons – must have the value 1. Only one photon is confined at the initial state $\lambda^* = 2L$ and creates a standing wave with counter-propagating half waves in a phase relation π. This unit interacts with a thermal free photon. Details of the interaction are subject of Chap.7.

7. Energy conservation is equivalent to momentum transfer between free-photon and confined-photon half waves and the intrinsic Doppler shift

To see what happens in a collision, the left side of the averaged magnitude of momenta i.e., the energy conservation equation (Eq.41, n = 1) is treated as if the involved photons denoted in curly brackets are preparing the collision; that is, fictitious momentum portions denoted in square brackets are already separated to change the photon momentum values.

$$\{\alpha\}+\left\{\frac{1}{2}\right\}+\left\{\frac{1}{2}\right\} \Rightarrow \{\alpha D'+[\alpha(1-D')]\} \;+\; \left\{\frac{1}{2}\frac{1}{D'}-\left[\frac{1}{2}\left(\frac{1-D'}{D'}\right)\right]\right\} \;+\; \left\{\frac{1}{2}D' \;+\; \left[\frac{1}{2}(1-D')\right]\right\} \tag{42}$$

Of course, the fictitious momentum portions denoted in square brackets add up to zero. They are arranged on the left as losses and on the right as a gain:

$$\alpha(1-D') \;+\; \frac{1}{2}(1-D') \;=\; \frac{1}{2}\,\frac{1-D'}{D'} \tag{43}$$

By factoring out the factor (1-D), the equation gains the form of a fusion between the free photon α and the half wave “$\frac{1}{2}$”of the confined photon:

$$\alpha+\frac{1}{2} \;=\; \frac{1}{2}\,\frac{1}{D'} \qquad \text{"}Fusion\text{"} \tag{44}$$

Consequently the counter-propagating **second half wave** (second “$\frac{1}{2}$” in Eq.42 left) appears as a decay after multiplying α in Eq.44 by the Doppler factor D´:

$$\frac{1}{2}=\alpha D'+\frac{1}{2}D' \qquad \text{"}Decay\text{"} \tag{45}$$

CONCLUSION 2. In contrast to the ***Doppler framework*** *(see conclusion 1), in the* ***energy framework*** *the free photon enters the system it collided with and undergoes a fusion process with the first half-wave of the confined photon. This leads to a blue shift. The second half wave decays to the Doppler-shifted free photon and suffers a corresponding red-shift. The decay of the second half wave can be regarded as an* ***intrinsic Doppler shift*** *which takes place within the photonic mass and not in the space between the colliding - and the laboratory system.*

By addition and subtraction of equations 44 and 45 and substitution of the D expressions by the mass – photonic mass - equivalence equations 37 and 38, equations 1 and 2 re-emerge:

$$\begin{aligned} \alpha+1 &= \alpha D' \;+\; \frac{1}{2}\underbrace{\left(\frac{1}{D'}+D'\right)}_{2\gamma'} \qquad \text{"}Magnitude\ of\ Momentum\ (Energy\ Conservation)\text{"} \\ \alpha \;\; &= -\alpha D' \;+\; \frac{1}{2}\underbrace{\left(\frac{1}{D'}-D'\right)}_{2\beta'\gamma'} \qquad \text{"}Momentum\text{"} \end{aligned} \tag{46}$$

Of course the fusion and decay equations (Eq.44 and 45) are also solutions of the Compton formula, since they depend solely on D´ (see Eq.3 and 10):

$$D'=\frac{1}{1+2\alpha} \tag{47}$$

8. Geometric requirements during fusion and decay of a Compton free photon for an in-phase situation

In Fig.7, the geometrical situation of a Compton collision for the in-phase situation as shown in Fig.6 (left graph) is sketched. Together with equations 44 and 45 and the substitution $\alpha = \hbar k / mc^2 = k / k^*$, where k and k^* are the wave vectors of free- and confined photons, the following geometrical process occurs:

The fusion formula (Eq.44) and the energy conservation behind it suggest that the free photon k must penetrate into the cavity although, for confined photons the cavity walls are impenetrable. It "fuses" with the front half-wave $\frac{1}{2}k^*$ and induces a blue shift to $\frac{1}{2}k^* D'^{-1}$(see dotted line in Fig.7). At the same time, when the free photon enters the cavity, the second half-wave $\frac{1}{2}k^*$ reflects from the rear side of the cavity unshifted because the wall is still at rest. Thus, this scenario differs from the one shown in Fig.3, in which the rear side moves with β*c and the half-wave undergoes a Doppler red shift ($\frac{1}{2}k^* D$). Therefore, to fit into a slanted cavity structure, the second half wave must "decay" as described in Eq.45. After the collision, the cavity moves with $\beta' c$ and with respect to the observer at rest <u>all photons have undergone Doppler shifts</u>.

A phase synchronization between the colliding and the confined photon in a Compton collision is unavoidable. The case with phase mismatch is the subject of Sect.10. Before this, the fusion equation (Eq.44) as understood in this Section leads to a number of interesting conclusions about quantum mechanical properties.

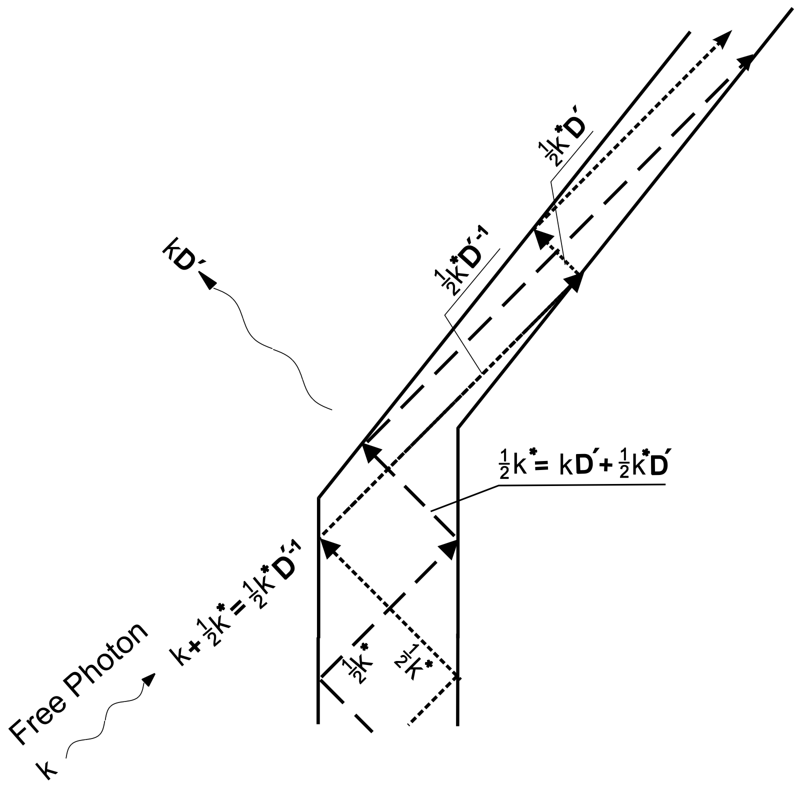

Fig.7: Sketch of a Compton collision of a free photon k in phase with the confined photon of a cavity. The confined photon k^* is split into two half-waves in the framework of Eq.41. The free photon “fuses” with the front half-wave $\frac{1}{2}k^*$ (dotted line) and increases its momentum. The second half-wave (dotted line) is transported from a cavity at rest into a moving cavity. Therefore it “decays” and emits the recoil photon kD′. Details are described in the text.

9. Motion by stop-and-go displacement - a key for understanding quantum mechanical probability density?

Let us assume that a free photon is absorbed by the cavity and not reflected immediately. It stays fused with the first half-wave of the confined photon. In this phase, the cavity moves with a velocity βc corresponding to $\gamma - 1 = \frac{2\alpha^2}{1+2\alpha}$ (see eq.4). If for any reason the second half-wave does not decay spontaneously with the emission of kD (the decay is shown in Fig.7), its reflection stops the motion. Then the first half-wave reflects at the interior side of the front mirror and the period starts again. The stop-and-go motion continues as long the free photon remains absorbed. Figure 8 shows a complex Minkowski space-time presentation of this case for a number of reflections.

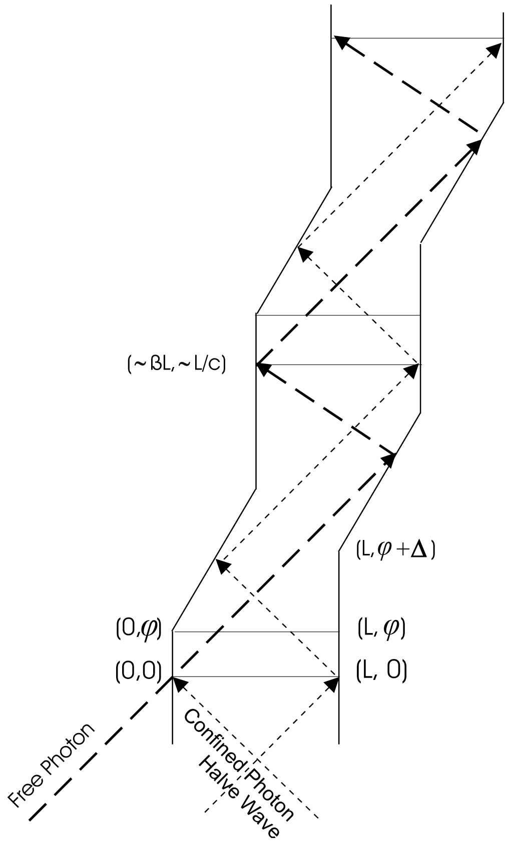

Fig.8: Sketch of `stop-and-go´ motion of a cavity after fusion of a free photon with the first half-wave of the confined photon and continuous reflections

This concept seems to lead directly to a well-known quantum mechanical description. The recoil velocity βc can be determined using Eq.4 and the $\gamma(\beta)$-equation. We have:

$$\beta = \frac{2\alpha\,(1+\alpha)}{1+2\alpha+2\alpha^2} \approx 2\alpha \quad if\ \alpha << 1 \qquad (48)$$

After the fusion of the free photon, the cavity moves with the velocity $v = \beta c$. The flight time of the first half-wave to the opposite mirror is $t_+ \approx L/c + \beta t_+$ and back to the front mirror is $t_- \approx L/c$. Thus, with Eq.48 the time-averaged velocity $\hat{\beta} c$ of the cavity is

$$\hat{\beta} c = \frac{\beta c \cdot t_+ + 0 \cdot t_-}{t_+ + t_-} \approx \frac{\beta c \cdot \frac{L/c}{1-\beta} + 0 \cdot L/c}{\frac{L/c}{1-\beta} + L/c} = \frac{1}{2}\beta c\,\frac{1}{1-\beta/2} = \alpha c\,\frac{1}{1-\alpha} \qquad (49)$$

$\hat{\beta} \approx \alpha \quad if\ \beta << 1$

or re-written in physical terms:

$$m\hat{v} = \hbar k \tag{50}$$

which is equivalent to the well-known expression of the de Broglie relation between momentum and wavelength. The conclusion is that the average momentum of the photonic mass is equal to the momentum of the absorbed free photon**.** However the velocity of a stop-and-go cavity has a fictitious meaning since it is either zero or represents a Compton recoil. The same is true for its averaged magnitude of momentum i.e., for the kinetic energy of the photonic mass. It is also fictitious.

It is interesting to note that the discontinuous stop-and-go motion of the cavity changes into a forward-backward "vibration" if the observer itself moves with the velocity $\hat{\beta} c$. The advantage of this consideration is that the cavity has at each instant of time a definite kinetic energy, corresponding to $\frac{1}{2}\hat{\beta}^2 = \frac{1}{2}\alpha^2$. It turns out, that under the above restriction the time-averaged kinetic energy derived from Eq.49 is a factor of 4 smaller than that of the Compton collision mode ($\frac{1}{2}\beta^2 = 2\alpha^2$, see Eq.48).

Now the cavity is placed into a box with infinitely deep rectangular potential walls with side length L. The initial state is an electromagnetic wave with the characteristic wavelength $\lambda = 2L$. Using $\hat{\beta} = \alpha$ (see Eq.49), the time-averaged kinetic energy $E_o \approx \frac{1}{2} m \hat{\beta}^2 c^2 = \frac{1}{2} m\alpha^2 c^2$ is:

$$E_0 \approx \frac{h^2}{8mL^2} = \frac{\hbar^2 k^2}{2m} \tag{51}$$

This is exactly the well-known value of the zero-point energy per axis [16]:

$$E_0 = \frac{\hbar^2 k^2}{2m} \; j^2 \; , \tag{52}$$

where j = 1 corresponds to the ground state of a particle with the mass m, which is confined in an area with the characteristic length L.

After the fusion, the mass moves in the box in a stop-and-go-manner with the average velocity $\hat{\beta} c$, but with a limited lifetime because of collisions with the box wall. In a simple approximation, the statistical lifetime is proportional to the remaining flight path between particle after flight reversal and wall of the box. After the decay, the free photon moves with the speed of light, reflects at the box wall and returns to the mass. In the course of this process, the mass moves back and forth with the fictitious velocity $\hat{\beta} c$ and tends to be present with a maximum probability around the center of the box as can be seen in Fig.9.

Higher modes of the wave ($j = 2,3$ ..) lead, because of $\alpha \to j\,\alpha$ (see Sect.3.5), to a quadratic increase of energy in Eq.48 as well as in Eq.52. We can say:

CONCLUSION 3: Energy conservation suggests that photonic masses absorb free photons (see Sect.7). This is true for the time span of reflection and even for the time span of many internal reflections. In the latter case the de Broglie relation is valid. The particles move in a stop-and-go-mode with a time-averaged momentum equal to that of the absorbed free photon.

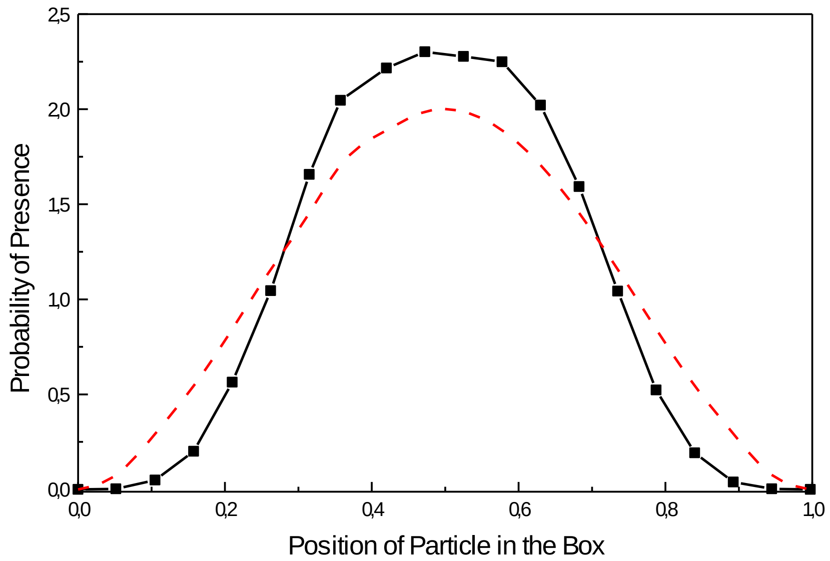

Fig.9: Numerical simulation of the probability of presence of a photonic mass particle in its initial state in a box with side length L= 1 (solid line) versus the quantum mechanical probability $\sin^2(\pi x / L)$ (dashed line)

The stop-and-go motion also yields what could be called a tramp model, because the momentum of an absorbed photon is used to move a photonic mass for a arbitrarily long time period with $\hat{v} = h / m\lambda$. If the photon is emitted in the forward direction, the photonic mass is at rest again. In principle, this effect makes it possible to cover distances in space without energy consumption. This is in accordance with energy conservation, because the potential difference between start and end points of motion is zero. In cases with potential differences ≠ 0, the captured free- as well as the confined photons change momentum in accordance with the energy conservation. This is subject of Section 12.

10. Frame of fusion and decay during a phase mismatch and phase adaptation. Discontinuous motion

The problem formulated in Sect.5 (Fig.6, left graph) deals with the possibility that a free photon collide a confined photon in a cavity with just the proper phase that is in-phase as shown in Fig.7. All other phase situations lead to mismatches of the standing wave situation in the cavity. As mentioned above, a way to handle this problem is to assume that in these cases a spontaneously generated pair of pool photons having the same momentum and correct phase appears in the cavity and fuses with the incoming free photon (see Fig.10).

In the course of this fusion, the pool photon $\hbar k^p$ (thick solid line, left hand with arrow) is converted into a confined one with two half-waves ($k^P \to \frac{1}{2}k^* + \frac{1}{2}k^*$). The second pool photon moves in the opposite direction (thick solid line to the right) and compensates the momentum of the escaping confined photon on the left $\frac{1}{2}k^* + \frac{1}{2}k^* \;\; \to k^P$ (dotted line), which escapes the cavity together with its second half-wave.

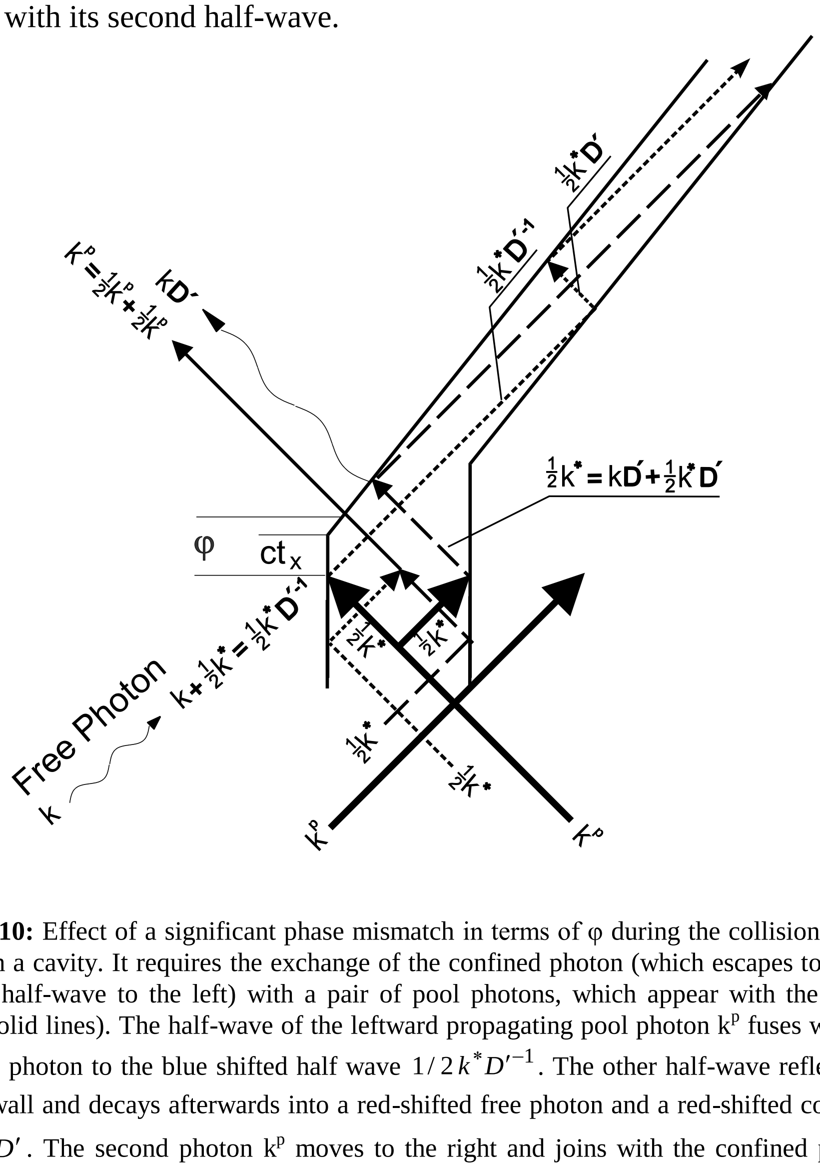

Fig.10: Effect of a significant phase mismatch in terms of φ during the collision of a free photon with a cavity. It requires the exchange of the confined photon (which escapes together with its second half-wave to the left) with a pair of pool photons, which appear with the correct phase (thick solid lines). The half-wave of the leftward propagating pool photon k^p fuses with the intruding free photon to the blue shifted half wave $1/2\,k^*D'^{-1}$. The other half-wave reflects at the rear cavity wall and decays afterwards into a red-shifted free photon and a red-shifted confined photon $1/2\,k^*D'$. The second photon k^p moves to the right and joins with the confined photon (which escapes $t = \varphi / c$ later to the left) to form a pair that changes the pool distribution (see text).

However, neutrality in the pool is not conserved perfectly, since there is a phase delay in terms of φ between the "absorption" of the pool photon (time point: free photon intrusion) and the emission of the phase-delayed confined photon into the pool ($k^* \rightarrow k^P$). This means that while the second pool photon $\hbar k^P$ (thick arrow) moves with the correct phase in the direction of acceleration, the confined photon escapes with a delay of t = φ/c in the counter-acceleration direction into the pool.

A probe particle (i.e., a proton, not shown in Fig.10) behind the accelerated photonic mass collides with a regular pool photon moving to the right but misses the counter propagating pool photon moving to the left since this is absorbed by the photonic mass. Thus, the probe moves in the direction of acceleration until it is stopped by the confined photon after the delay time $t_x = \varphi / c$. This motion will be called discontinuous motion as a variation of the stop-and-go-mode described in Sect.9. Depending on the magnitude of phase mismatch the magnitude of the displacement ranges between 0 and $r = 0.87 \cdot 10^{-15} m$ (radius of the proton) and is, on average, ½ r. This process propagates leftward with the speed of light and is unlimited in time since the phase distortion is conserved. It could be mistaken for a force of attraction but is not really such a force. As described in Sect.9, the discontinuous motion of a probe mass reflects the principal property of space, which allows motion without energy consumption.

Each incoming free photon triggers a discontinuous motion. It is clear that reflections at single particles are governed by the Thomson cross-section. All Compton photons (free photons) with a wavelength comparable to the dimension of the photonic mass ($L \approx r_0$) collide with a probability of about 1 and free photons with lower energy collide with a reduced probability proportional to r_0^2 / λ^2, unless a mirror-like conglomeration of photonic masses is larger than the wavelength. In this case, the probability of reflection is also 1.

The power P_{in} carried by a free photon with energy hc/λ that arrives within a time interval Δt at a photonic mass is:

$$P_{in} = \frac{hc}{\lambda \Delta t} \qquad (53)$$

The probability of reflection at the photonic mass as described by Thomson reduces P_{in} to P_R. Exceptions are the upper mentioned mirror-like conglomerations of photonic masses. If they are larger than the wavelengths of free photons then the factor in P_R^M remains equal to 1 ("M" stands for mirror):

$$P_R = P_{in} \frac{r_0^2}{\lambda^2} \qquad P_R^M = P_{in} \cdot 1 \qquad (54)$$

Even for a low-energy free photon, each reflection described by Thomson scattering at a single charge or at mirror-like conglomerations triggers the delayed emission of a high-energy confined photon (having the momentum hc/r_0) with the power of:

$$P_{r_0} = \frac{hc}{r_0\,\Delta t}\,\frac{r_0^2}{\lambda^2} \qquad\qquad P_{r_0}^M = \frac{hc}{r_0\,\Delta t} \tag{55}$$

Using Eq.53 to replace the factor Δt in Eq.55, we have:

$$P_{r_0} = P_{in}\,\frac{r_0}{\lambda} \qquad\qquad P_{r_0}^M = P_{in}\,\frac{\lambda}{r_0} \tag{56}$$

Finally the photon flux j as well as j^M with the dimension: number of photons with momentum hc/r_0 - per area F and per second is:

$$j = P_{in}\,\frac{1}{F}\,\frac{r_0}{hc}\,\frac{r_0}{\lambda} \qquad\qquad j^M = \frac{\lambda^2}{r_0^2}\,j \tag{57}$$

A probe particle (proton) with a cross-section of $\sigma \approx \frac{\pi}{9} r_o^2$ is exposed to this photon flux (r_0 is the classical electron radius). It collides with a high-energy pool photon and a time φ/c later with a high-energy one moving in the opposite direction. As already mentioned, a displacement $\hat{d}$ with average value of $\frac{1}{2} r_0$ will take place during each collision with a probe particle. Therefore the expressions for the flux in Eq.57 will be called the displacement flux.

The product $\sigma \cdot j$ gives the number of collisions. It is a measure for the average displacement per second:

$$\hat{d} \approx \frac{1}{2} r_0\,\sigma j = \frac{\pi}{18}\,\frac{P_{in}}{F}\,\frac{r_0^4}{hc}\,\frac{r_0}{\lambda} \qquad\qquad \hat{d}^M \approx \frac{1}{2} r_0\,\sigma j^M = \frac{\pi}{18}\,\frac{P_{in}}{F}\,\frac{r_0^3}{hc}\,\lambda \tag{58}$$

The average displacements per second are tiny even for strong fluxes (see Eq.58, right-hand formula). For instance, for visible light with a power density P_{in} of $1 kW/mm^2$ the discontinuous motion per second is far below r_0. However, with high power laser beams in the MW/GW-area, measurable effects can be expected, provided the mechanism can really be set up.

It is possible that such effects can already be explored and described. A likely candidate is the enigmatic photophorese first described by F. Ehrenhaft [17], although it was later interpreted as a radiometer effect [18].

Another phenomenon described by references [19, 20] gives information about motion effects in the vicinity of accelerated masses comparable to first order effect in terms of β. A displacement flux resulting from accelerated masses could be deduced as follows: Deviating from the concept described in Equations 53 to 58, we start with the scenario that mass points m in solid matter of mass M are positioned at fixed distances from each other and the coupling of an external force is done by hypothetical reflecting lattice photons. To first order in β, the velocity change Δv during the time interval $\Delta\nu = \lambda / c$ depends on the acceleration "A" and the momentum transfer of the photon reflection:

$$\Delta v = A\,\Delta t$$
$$m\,\Delta v \approx \frac{2h}{\lambda} = m\,A\,\Delta t = m\,A\,\frac{\lambda}{c} \qquad (59)$$
$$\lambda = 2\cdot\sqrt{\frac{h\,c}{m\,A}}$$

The wavelength is virtual, since for weak accelerations the wavelength far exceeds real lattice distances. Depending on the phase situation (see Fig.10), each reflection can lead to the emission of a high-energy confined photon. The resulting displacement flux j_A is proportional to $1/F$, to the number of mass points (M/m) in the accelerated mass and to the reciprocal reflection time λ/c:

$$j_A = \frac{1}{F}\,\frac{M}{m}\,\frac{1}{\lambda/c} \qquad (60)$$

To demonstrate the magnitude of the displacement flux, the equivalent of $M = 1kg$ neutrons (with the density of water) is accelerated with $A = 1m/s^2$. The wavelength of the force-coupling photons is $\lambda \approx 20\,m$ and the displacement flux in a square of $10\,cm\,x\,10\,cm$ is $j_A \approx 10^{36}$ displacements per second. A probe near the square with a cross-section of about $\pi\,r_0^2$ is displaced with each collision (in the direction of acceleration) by $\frac{1}{2}r_0$. Let d be the sum of displacements in one second:

$$d \approx \tfrac{1}{2}r_0\cdot\frac{\pi}{9}r_0^2\cdot j_A \approx 10^{-46+36} = 10^{-10} \qquad (61)$$

It is true that the flux is extremely high but the Thomson cross-section reduces the effect considerably. Under certain circumstances such small effects can be measured i.e., the very low proton cross-section of approximately $10^{-30}m^2$ can be increased by alignment effects of single crystals.

11. Inertia of a photonic mass

If one applies Newton's third axiom of inertia to a photonic mass then the following happens: During the reflection the free photon transfers momentum to the photonic mass. Simultaneously the photonic mass transfers momentum to the free photon of equal value and of opposite direction to the free photon.

Let us examine this in a gedankenexperiment where photons are confined in a box. Via a spring a constant force shall act on the box. An observer in the system of the accelerated box states that photons which reflect at the side of the spring gain a blue shift and those reflecting at the opposite side gain a red shift (see Fig.3). The resulting momentum during a reflection period causes a counterforce against the spring. The momentum obeys Eq.36 and is equal to a photonic mass in motion but here it belongs to an accelerated system. If the acceleration ends the blue- and red shift processes have also ended. The wavelengths of the photons remain unchanged in comparison to the beginning of the experiment. However an observer in the laboratory system measures a resulting photon momentum as described in Eq.36.

This behavior is also visible in Fig.7. In analogy with the accelerated box, the fusion process (eq.44) leads to a blue shift and the decay process leads to the red shift (eq.45) of the confined photon. The point is that all these processes are affected by the free photon itself.

To translate these facts into the macroscopic: If one throws away (role of free photon) a stone consisting of photonic masses, then combined blue and red shifts generate the inertial counter force which is experienced by the hand as a counter pressure.

The inertia of photonic masses shows no difference with respect to ordinary masses. However, it could be demonstrated that colliding free photons are directly responsible for the inertia of a photonic mass and not reaction processes in the mass itself. This might be a progress in the understanding of inertia.

12. A photonic mass in the gravitational field

It is well known that under the action of the gravitational field electromagnetic waves suffer wavelength shifts [21]. The momentum loss $k'-k$ of a photon is proportional to the strength $\vec{g}$ of the gravitational field and to the path $\vec{s}$:

$$k' = k\left(1-\frac{\vec{g}\,\vec{s}}{c^2}\right) \qquad (62)$$

The same is true for the confined photon in the cavity. Although it reflects back and forth, if it passes against the gravitation field it loses energy and momentum as described in Eq.62. Since the dimension of the cavity is $\frac{1}{2}\lambda$ the cavity consequently also expands. If the cavity moves into the gravitational field the situation is reversed [22]. To relate to Sec.9 and to the remarks on the tramp model an absorbed free photon of course undergoes the same wavelength shifts as the confined photon.

Assume a photonic mass with an absorbed free photon moving with its fictitious velocity against a gravitational field. The question arises what is the condition for a standstill i.e. the stop-and-go motion against the field is exactly compensated by the falling distance s. The fall $\vec{s}$ of the photonic mass in the time interval $t = L/c$ is $\vec{s} = \frac{1}{2}\vec{g}\,t^2$ where L is the dimension of the cavity. We have standstill if:

$$\hat{v} = \frac{1}{2}g\,t = \frac{1}{2}g\frac{L}{c} \qquad (63)$$

For realistic parameters such as $L = 10^{-15}m$ and $g = 10\,m/s^2$ the fictitious velocity of the order of $10^{-20}m/s$. Using the de Broglie relation the wavelength of the absorbed free photon for this case is $10^{13}m$. All wavelengths smaller than the standstill condition lead to a propagation of the photonic mass with de Broglie velocity against the gravitational field. The loss mechanism for the absorbed free- and con fined photons with effective mass m^* is the decrease of their momenta described by the energy loss $m^* \vec{g}\,\vec{s}$ in Eq.62. Thus, if nature allows it, aligned stop-and-go motions of particles with fictitious de Broglie momentum make it possible to overcome gravitational potentials with minimum energy consumption.

This has to be distinguished from the so called photon rocket [23] which was first cited by H. Sänger [24]. The repulsion in a photon rocket is provided by the emission of photons. This is an extremely energetic process, since after each emission of a photon and momentum transfer its energy counts as a loss. If no potentials are present the ratio energy/momentum is c while in the case of stop-and-go motion this ratio is zero. If gravitation potentials are present the ratio $g\,s/c^2$ is still low.

13. Conclusion

Both, classical masses and masses consisting of confined thermal photons in a cavity have the same behavior with respect to momentum and kinetic energy. This is the essence of the mass – confined photons – equivalence equations (eq.37 and 38). The cavity model depends on the existence of a photon pool, which compensates the confined thermal photon reflection momenta at the cavity walls by in-phase reflections. For example, the postulated photon pool can consist of the Casimir zero-point radiation together with a yet to be specified thermal contribution (see Sect.3.4 and 14)

Sect.2 demonstrates that momentum conservation and Doppler shift describe the Compton Effect of photonic masses exactly. Viewed from this perspective, the energy conservation seems to be unnecessary for 180°-collision processes with photonic masses. However it turns out that:

- Energy conservation requires that for collision processes with photonic masses the sum of all Doppler shifts of the involved photons has to be zero (eq.43). This is interpreted as the fusion between the free- and the first half wave of the confined photon (blue shift, see eq.44). Afterwards the unshifted second half wave of the confined photon decays to a red shifted free- and a red shifted second half wave of the confined photon as it is described in eq.45

- In principle the fusion-decay process of the recoil allows a separation of absorption and emission process. During the period of separation the motion of the photonic mass is consistent with the de Broglie relation between momentum and wavelength. However statements about motions with a fictitious velocity together with fictitious kinetic energy were required.

Collisions of free photons with photonic masses will generally suffer a phase mismatch between free and confined photons. This will lead to a distortion of the pool photon distribution with the effect that a probe mass behind the accelerated photonic mass experience a discontinuous motion with fictitious velocity (see Sect.10).

So far, differences between the statements of Ordinary Relativity Theory [25] and the model presented here are evident. Ordinary Relativity predicts in third order of β a weak induced motion of a probe masses in the direction of acceleration in the environment of accelerated masses, while a photonic mass induces an acceleration dependent discontinuous motion of a probe with a fictitious velocity.

The inertia of photonic masses results from the fact that the free photon that intrudes into the cavity fuses with the confined photon and causes a blue and red shift as described in Eq.36 which indicates the inertial counterforce and reflection. So seen the free photon carries the counterforce into the photonic mass

Since photons experience Doppler shifts in gravitational fields, confined photons as well as absorbed free photons change momentum as well. The consequence is a field dependent spacing of the cavity mirrors. It is demonstrated that in principle the stop-and-go motion of particles with fictitious de Broglie velocity can be used to overcome gravitational potentials with minimum energy consumption.

14. Outlook

The presented model lives from an outer pressure to compensate the interior pressure of the cavity (see Sect.3.4). The zero point radiation is by far not sufficient to provide this (a factor of 76 too small). The outer pressure can be provided by a dense, isotropic flux j of thermal ultralong wavelength photons ($\tilde{\lambda} \approx 10^{25}\, m$) in the space as reported in ref.15. This flux causes attraction forces between charges similar to gravitation by scattering and mutual screening. A set of parameters adapted to gravitation suggests that each charge is penetrated by about $10^{60} - 10^{65}$ photons/s and the diameter of the cross section for scattering is as small as the Plank length.

If one compares the expansion force of a confined thermal photon (see Eq.32) with the compression force generated by the flux j of ultralong wavelength photons given in ref.16 (p.48, point 2), we have:

$$\frac{1}{2}\frac{hc}{L^2} = 2j\frac{h}{\tilde{\lambda}} \qquad (64)$$

$$j = \frac{1}{4}\frac{c\tilde{\lambda}}{L^2} \approx 10^{63} \text{ photons/s} \qquad (65)$$

This indicates that both models might have a common basis. This gives hope that a theory could be found where mass, gravitation and quantum mechanic can be harmonized.

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