Variation of mass and time conversion of rest into a non-rest visible photon or vice-versa

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Abstract. In this work, the time rest time of incidence photon on reflecting surface before going to the motion was calculated for a visible photon of wavelength (380nm to 750nm) be found in between 1.27fs to 2.50fs. This time is also known as the time needed for a visible photon to come rest from motion and motion from rest from the reflection surface, for the same photon. This times shows how long a photon are in rest on the surface and then come motion or non-rest photon. More clearly one can understand the decay time of photon that rest to non-rest and non-rest to rest, self-energy time, mass variance time, quantization time and other information related to time. On other hand, the variation of mass of photon with time closure the surface is also studied.

1. Introduction

The concept of a photon is one of the debated issues in physics fields in past but still unclear. Muthukishna et al. in 2003, described photon as a classical electromagnetic field plus the fluctuations associated with the vacuum. The duality conceptions of photon have co-existed since antiquity. Quantum theory of light introduces vacuum fluctuations into the radiation field and endows field states with quantum, many-particle correlations. The particulate nature of the photon is evident in its tendency to be absorbed and emitted by matter in discrete units, leading to quantization of light energy while the localization of photons by a photodetector makes it possible to define a wave function for the photon, which affords a first-quantized view of the electromagnetic field [1].

Planck’s proposed that temperature is proportional to frequency while Boltzmann knew that temperature is proportional to the energy. The energy is proportional to frequency (\( E = hf \)), for monochromatic beam energy is \( nhf \). To study the physical nature of matter-wave scientist propose, like the photon, a particle is an excitation wave of a real physical field and different types of particles have different excitation modes in the same field. This concept suggests that various quantum wave equations like the Klein-Gordon equation, the Dirac equation and the Schrödinger equation, etc. [2].
In noncommutative QED, the study of two-photon behaviour as covariant gauge and in arbitrary space-time dimensions, generally and self-energy of a photon is in form of transverse [3]. The self-energy of a photon in a complete one-loop has real and imaginary parts, for photon, gluons, electrons and quarks at finite temperature. Some light is also shed on the validity of the weak coupling limit assumption (g << 1) or equivalently the high-temperature assumption. Moreover, gauge dependence of the fermion self-energy beyond the HTL approximation is considered [4].

Tomonaga’s conjecture shows self-energy of photon should vanish to zero and the photon’s self-energy diagram violates the Lorentz invariance. In addition, there occurs no wave function renormalization of a photon in the exact Lippmann-Schwinger equation for the vector potential and this confirms that the conjecture is correct [5]. The self-energy of the photon has been included in the renormalization scheme by throwing away the quadratic divergence terms and by keeping only the terms that have the same shape as the Lagrangian density of photon. The self-energy of photon should vanish to zero, this vanish is basically due to the self-energy of photon arising from the vacuum polarization diagram. The evaluation of the self-energy of the photon was carried out just in a similar way to the Feynman diagram calculations. The effective Lagrangian density, Heisenberg and Euler proposed can take into account the effects of the vacuum polarization which is the same as that of the modern version. The self-energy of a photon is entirely based on one simple relation which is called gauge condition for the vacuum polarization tensor.

Renormalization scheme for the electroweak standard model is present, electric charge and the masses of the gauge bosons. The photon is treated as a simple substructure by quantum electrodynamics. Field renormalization respecting the gauge symmetry gives finite propagators and vertex functions [6]. The Feynman rules in momentum space and derives some expressions that give rise to certain infinities (photon self-energy, electron self-energy and vertex correction) [7]. The photon has several properties that distinguish it from all other subatomic particles and a high energy photon can split up into two or more low energy photons (down conversion) and vice versa (up conversion). This show the breakdown of photon or photon is a composition of numbers of the photon. The transformation conforms to the laws of conservation of momentum and energy for down-conversion, moreover, a high-frequency photon should have more rest mass or invariant mass than a low-frequency photon [8].

The relativistic mass increases with velocity are not compatible with the standard relativity theory and the same difficulty occurs with rest mass. The relativistic mass and rest mass is appropriate to replace the equation $E = mc^2$ by the true Einstein’s equation $E_0 = mc^2$, where $E_0$ is the rest of the energy and $m$ is the mass [9]. Photon mass is ordinarily assumed to be exactly zero but no experimental evidence was found but various experimental methods are used to estimate upper limits on the photon mass. Photon mass is not a universal constant but instead depends on the photon energy.

The phenomenon of a photon fluctuating from nothing is a commonly described quantum physics possibility and speculations also abound that the universe may be a consequence of an earlier quantum fluctuation [10], [11]. The primeval photon for cosmology is discountenanced on the premise that from uncertainty relations has short-lived only about $10^{44}$ seconds. Typical fluorescence from commonly used organic fluorophores lasts only some hundred picoseconds to some tens of nanoseconds. The decay lasting up to 10ps and at first glance a photo-diode and a fast oscilloscope or some similar electronic transient recorder [12].

Experimentally, a lifetime of the photons in a cavity containing a medium exhibiting strong positive dispersion. Electromagnetically, induced transparency regime in which light propagates at a group velocity of the order of $10^4$ m/s. The lifetime of the cavity photons is governed by the group velocity of light in the cavity and not its phase velocity [13]. The timing precision is better than 1 ns with $1000 \times 1000$ pixels position resolution and up to one megacounts/s processing rate [14].
The minority-carrier lifetime is a crucial parameter for the improvement of electronic or optoelectronic materials and particularly solar cells and time-correlated single-photon counting (TCSPC) for the measurement of time-resolved photoluminescence (TRPL) and the direct determination of the effective minority-carrier lifetime in silicon. The TRPL technique is in very good agreement with quasi-steady state and transient photoconductance results. The demonstration of effective carrier lifetime of silicon substrates over a broad range of values, that is from a few $\mu$s and less than $500\mu$s [15].

Pile-up restrictions of most other detectors limit the count rate such that approximately 1 in 100 pulses yields a photon. Long lifetime probes such as lanthanides have lifetimes in the millisecond regime was demonstrated in living cells. This technique allows the measurement of lifetimes down to $\sim 1\mu$s. Lifetimes around $1\mu$s have been measured with several transition metal probes using a 54 kHz frame rate [16], [17], [18]. The orthogonal nature of space and time accounts for particle invariance during time progression. Inertial rest mass does not rarely along time paths because it resides in space. Photon kinetic energy does not rarefy along space paths because it resides in time. Photon kinetic energy in time cannot be fractionated by material, space-residing devices. A quantized particle with rest mass requires a space volume and a time interval. Photon energy is created when work is done upon a charge and also generated by the release of stored work. Photon energy oscillation occurs and it does so in time.

The negatively charged nitrogen-vacancy (NV−) centre in diamond is of great interest for quantum information processing and quantum key distribution applications due to its highly desirable long coherence times at room temperature. The challenges for these applications involves the requirement to further optimize the lifetime and emission properties of the centres. The demonstration shows the reduction of the lifetime of NV− centres and an increase in the emission rate. The experiment shows that coating the NDs in a polymer film 63% reduction in the lifetime on average [19].

Reflection of light is the bouncing back of a wave after meets with a surface without absorbing all of the light energy example mirrors and other smooth surfaces. When photon approaches the surface of the mirror with $z = ct$ and last photon in the pulse to be $z = c(t - T)$. Therefore, the first photon intercepts the mirror at $t = 0$ and the last photon at the solution of $c(t - T) = \beta c t$. There is no loss of generality in assuming that each photon in the incident pulse is absorbed and emitted by the mirror with no delay. The reflection for the first photon pulse is $z = -ct$ and the last reflected photon is $z = -c(t - T_m) + \beta c T_m$. Let $N$ be the total number of photons per unit area in the incident pulse, necessarily equal to that in the reflected pulse, the total energies per unit area in the incident and reflected pulses are

$$\varepsilon_i = N\hbar\omega_i = I_i T_i$$
$$\varepsilon_r = N\hbar\omega_r = I_r T_r$$

Where $2\pi \hbar$ is Planck’s constant, $I_i$ and $I_r$ intensities of pulses of uniform distributions of photons. The conventional sinusoidal plane wave reflection coefficient for mirror does not have unit magnitude, there is no violation of energy conservation for pulses of finite duration. The energy in the incident pulse is partly transferred to the stretched or compressed Doppler-shifted reflected pulse and partly converted to work done on the mirror [20]. Reflectance is from a surface is an intrinsic optical property of thin films and essential in determining the colour, transparency and polarization characteristics of the film. Reflectance depends on the energy band structure and associated plasma frequency of charge carriers. The high reflection spectral regions are different for metals, semiconductors and insulators. Some materials are used for mirrors because they reflect all spectral components of white light with little absorption or transmission.
2. Method and Material

2.1. Phenomena

Let us consider a visible photon incidence on the reflecting surface whose wavelength 380nm to 750nm. When photon incidence on reflecting surface the non-rest photon come to rest and after an instant again come to motion (no-rest). The time between rest and non-rest mass or non-rest and rest mass of photon help to understand the phenomena of rest and non-rest photon.

![Figure 1: Reflection of visible Photon](image)

Here $\lambda$ is the wavelength of visible photon and $d$ is the maximum length of the photon which here is equivalence to wavelength length. Now from the basic formula

$$Time (T) = \frac{Distance(d)}{Velocity(c)}$$

Here $d$ is distance travel of visible photon travel on reflecting the surface and $c$ is the velocity of the visible photon. As photon incidence on any reflecting surface photon come to rest and after a certain time the same photon goes with a velocity of the visible photon.

Let the photon incidence on the surface with rest mass energy of photon $E = hf$ and $E = m_0c^2$ and relativistic mass of moving photon in free space is defined as

$$m = \frac{m_0}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$$

Here $m_0$ is rest mass of photon and $v$ is the velocity of the photon. The rate of mass changes as the velocity of photon goes to change that is from motion to rest (incidence on reflecting surface from free space) and rest to motion (from reflecting surface to free space). The relativistic rate of masses changes when motion photon goes to incidence on the surface (motion to rest) is as

$$\left(\frac{dm}{dt}\right)_{M-R} = \frac{dm_0}{dt} \frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}} + m_0 \frac{d\left(1 - \left(\frac{v}{c}\right)^2\right)^{\frac{1}{2}}}{dt}$$
\[
\frac{dm}{dt}_{M-R} = m_0 \frac{d\left(1 - \left(\frac{v}{c}\right)^2\right)^{-\frac{1}{2}}}{dt}
\]

Since \(m_0\) is the rest mass of the photon.

\[
\frac{dm}{dt}_{M-R} = m_0 \times -\frac{1}{2} \left(1 - \left(\frac{v}{c}\right)^2\right)^{-\frac{3}{2}} \times -\frac{2}{c^2} \frac{dv}{dt}
\]

\[
\frac{dm}{dt}_{M-R} = \frac{m_0}{c^2} \left(1 - \left(\frac{v}{c}\right)^2\right)^{-\frac{3}{2}} \frac{dv}{dt}
\]

This is the equation of rate of mass change as photon goes rest from motion or motion to rest. Here two cases arise

2.1.1. Case I

If photon goes to rest from motion that is photon incidence to the reflecting surface as shown in figure 1. In this case, time tends to zero hence the rate of change of mass doesn’t take place as the photon goes to rest. Therefore equation (1) with a limit to time is zero or constant which means photon at rest has constant rest mass.

\[
\frac{dm}{dt}_{M-R} = 0
\]

\[
m = \text{Constant or 0.}
\]

2.1.2. Case II

If photon goes to motion after reflecting from reflecting surface as shown in figure 1. In this case, time tends to infinity or increase hence rate of change of mass takes place as photon goes to motion. Therefore equation (1) with a limit to time shows photon mass goes decrease as photon goes away from reflecting surface for a certain instant.

\[
\frac{dm}{dt}_{R-M} = \frac{m_0}{c^2} \left(1 - \left(\frac{v}{c}\right)^2\right)^{-\frac{3}{2}} \frac{dv}{dt}
\]

\[
\frac{dm}{dt}_{R-M} = m_0 \left(1 - \left(\frac{v}{c}\right)^2\right)^{-\frac{3}{2}} a
\]

On integrating left side with masses and right with time \(t=0\) to \(t\)

\[
\int_{m_0}^{m} dm = \frac{m_0}{c^2} \int_{0}^{t} \left(1 - \left(\frac{v}{c}\right)^2\right)^{-\frac{3}{2}} a \, dt
\]
\[ m - m_0 = \frac{m_0}{c^2} \int_0^t \left( 1 - \left( \frac{v}{c} \right)^2 \right)^{\frac{3}{2}} \, dt \]

\[ m = m_0 + \frac{m_0}{c^2} \int_0^t \left( 1 - \left( \frac{v}{c} \right)^2 \right)^{\frac{3}{2}} \, dt \]

The masses of a visible photon is calculated by some authors like Tue et al., as \( 10^{-36} \text{kg} \) and Pariser by using He-Ne laser of wavelength 6328\text{A} is \( 8.56 \times 10^{-38} \text{kg} \). The average mass of the visible photon is \( \frac{10^{-36} + 8.56 \times 10^{-38}}{2} = \left( \frac{10^{-36} + 0.0856 \times 10^{-36}}{2} \right) = 0.5428 \times 10^{-36} \text{kg} \).

Non-rest mass of visible photon \( (m_p) = 0.5428 \times 10^{-36} \text{kg} \)

The wavelength of violent visible photon minimum \( (\lambda_v) = 380\text{nm} = 380 \times 10^{-9}\text{m} \)

The wavelength of red visible photon maximum \( (\lambda_r) = 750\text{nm} = 750 \times 10^{-9}\text{m} \)

Speed of photon \( (c) = 3 \times 10^8 \text{ms}^{-1} \)

Since we have

Time \( (T) = \text{Distance} \, (d)/\text{Velocity} \, (c) \)

On considering the violent photon incidence on the reflecting surface and come into rest with covering distance \( \lambda_v \). This distance is the minimum distance for the photon in which occupied the photon to come rest or rest to motion.

Now time for a violent visible photon \( (T_v) = \frac{\text{Minimu distance of Violent Photon} \, (\lambda_v)}{\text{Velocity of Visible light} \, (c)} \)

\[ T_v = \frac{380 \times 10^{-9} \text{m}}{3 \times 10^8 \text{ms}^{-1}} \]

\[ T_v = \frac{380 \times 10^{-17} \text{s}}{3} \]

\[ T_v = 126.67 \times 10^{-17} \text{s} \approx 1.27 \times 10^{-15} \text{s} = 1.27 \text{fs} \]

Also for Red visible photon \( (T_r) = \frac{\text{Minimu distance of Red Photon} \, (\lambda_r)}{\text{Velocity of Visible light} \, (c)} \)

\[ T_r = \frac{750 \times 10^{-9} \text{m}}{3 \times 10^8 \text{ms}^{-1}} \]

\[ T_r = \frac{750 \times 10^{-17} \text{s}}{3} \]

\[ T_r = 250 \times 10^{-17} \text{s} = 2.50 \times 10^{-15} \text{s} = 2.50 \text{fs} \]
As the minimum wavelength of the visible photon is the wavelength of the violent photon and the maximum is the wavelength of the red photon. Therefore the minimum distance before reflecting the surface photon come to rest for an instant time. For a red photon, the rest time is about $2.50\,fs$ while for a violent photon is about $1.27\,fs$. Hence for visible photon, the time needed for a photon to come to rest from motion or rest to motion lies in between $1.27\,fs$ to $2.50\,fs$.

3. Result and Discussion
The study of this work help to understand the nature of photon like variation of masses of the photon before and after reflection of photon from reflecting surface. As non-rest photon goes to reflecting surface and with the incidence of the photon on reflecting surface whole part of photon interact with the surface, therefore, the interaction of whole part of a photon is its wavelength. In our case, the photon goes to interact with its whole part therefore the rest time of the photon in reflecting surface is calculated $1.27\,fs$. But if photon doesn’t interact its whole part (partial part) the rest time interaction of photon on the surface is less than $1.27\,fs$. Similar case if applicable for all visible photon. The visualization of the case when photon interacting with reflecting surface with the partial part.

![Figure 2: a partial reflection of photon from reflecting surface](image)

Since all wavelength of visible photon lies in between $380\,nm$ to $750\,nm$ therefore the calculation of time for whole interaction of photon lies in between $1.27\,fs$ to $2.50\,fs$. The reflecting surface doesn’t the energy of the photon $(hf)$ but this energy goes to rest when interacting to the reflecting surface with these rest energy photon is also concluded to get rest for an instant. With calculating the time for whole photon part interaction on the reflection surface it was observed that as the wavelength of photon goes increases the time gap or in travel between rest and non-rest photon goes increase. These time help to understand all phenomena of photon like self-energy to accelerated the photon, arrangement of the direction of photon and energy, interaction and incidence angle, etc.

4. Conclusion
The time gap or in travel calculation between rest and non-rest are calculated using reflecting surface was calculated about femtosecond ranges from the visible photon. With the help of this information of time between the rest and non-rest photon different information of photon can be observed. The information that is beneficial to new physics like self-energy time of photon, increasing or decreasing the rate of mass of photon, variant of masses, quantization time of boson, and other information related to time. This calculation is based on theoretical assumption and reflecting phenomena of the visible photon.

5. Declaration statement
Availability of data and materials: The data was generated using MATLAB software for this work based on the equation derived above, the plot above is drawn using MATLAB code.

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