The interacting system of electrons, positrons and photons in high external electric and arbitrary magnetic fields

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January 2, 2022

Abstract

The connected system of Boltzman equations for the interacting system of electrons, positrons and photons in high external electric E and arbitrary magnetic H fields is solved. The consideration is made under the conditions of arbitrary heating and the mutual drag of carriers and photons.

The non-stationary and non-uniform distribution function (DF) of photons for the all considered cases is obtained. It is shown that the DF of photons have the stationary limit for the drift velocities $\left( \vec{u} \vec{q} / \hbar \omega_q \right) < 1$ and becomes exponentially grown by the time for the drift velocities $\left( \vec{u} \vec{q} / \hbar \omega_q \right) \geq 1$. It is shown that the mutual drag of carriers and photons leads to the formation of "quasi-particles" - the "electron dressed by photons" and "positron dressed by photons", i.e. the mutual drag plays the role of the dressing mechanism of carriers and leads to the renormalization of the mass and frequency of photons.

As a result of analyses of the phenomena of connected by the mutual drag system of carriers and photons we receive some fundamental results: a) the finiteness of the mass of photon (i.e. the rest mass of photons do not equal to zero); b) reality of takhyons as a quasi-particles with the real mass in amplifying system (or regime); c) identity of the mechanism of relativity and the Doppler effect which coincides with the renormalization of frequency or mass as a result of the mutual drag of carriers and photons at external field (force). These conclusions were received as a result of the fact that the relativistic factor enters to the expressions of the DF

*The results of this paper was reported on the V International Conference"Tousi-800 School"Shamakhy Astrophysical Observatory 14-17 October,1999 and the thesis of report is printed in [17].
of photons and other physical expressions in the first order in the form 
\[1 - \left(\frac{u^2}{c^2}\right)^{-1}\], instead the 
\[1 - \left(\frac{u^2}{c^2}\right)^{-1/2}\] in Einstein theory. It is shown that the relativistic 
effect of deceleration of time really taking place for the relaxation time of 
carriers or for the life time of carriers, or for the period of electromagnetic 
oscillations. The latest is a direct result of the Doppler effect. Also it is 
shown that the velocity of light is an averaged velocity of photons at the 
ground state, as well as a velocity of sound for the phonons.

1 Introduction

In earlier my publications made the theoretical investigation for the interacting 
system of electrons and phonons in semiconductors, semimetals and gaseous 
plasmas at high external electric and magnetic fields also under the conditions of 
the propagation of strong electromagnetic waves. In [1-4] the connected system 
of kinetic equations of interacting electrons, holes and phonons at high electric 
and magnetic fields was solved, with taking into account arbitrary heating and 
the mutual drag of carriers and phonons. For the phonons the solution of non-
stationary kinetic equation was found and was shown that the non-equilibrium 
and non-stationary distribution function of phonons has the stationary limit, 
when the drift velocity of connected by the mutual drag system of carriers and 
phonons is less than the velocity of sound \(u < s\). For the drift velocities 
\(u > s\) the distribution function of phonons becomes is exponentially grown by 
the time. It accords to the generation of intrinsic phonons and amplification of 
phonons introduced to the system externally (the stream of phonons).

It was shown that the mutual drag leads to the re-normalization the mass 
of carriers. As a result of the mutual drag electrons and holes are "dressed" 
by phonons and formed the "quasi-particles" which has the electrons or holes 
charge \((\pm e)\) and the phonons mass \(m = T_i/s^2\) (where \(T_i\) - is the temperature of 
the coupled by the mutual drag system of carriers and phonons) [1-5]. In weak 
electric fields the mass of phonons are \(m_o = T/s^2\). In the case of propagation 
of strong electromagnetic wave in semiconductors and semimetals at external 
magnetic field this lead to the cyclotron resonance on such "quasi-particles" 
with the frequencies \(\omega_H = (3/4)eH/\left[(T_i/s^2) \cdot c\right]\) [6,7]. It was shown in [7], that 
the effect of connection carriers and phonons as a result of their mutual drag 
is a common phenomenon. Really, as it follows from [7] under the conditions of 
longitudinal propagation of strong electromagnetic wave in semimetals with 
equal electron and hole concentrations the frequencies of Alfven and magneto-
sound waves are identically equal to each other and have the form:

\[\omega_A = \omega_{m,s} = kH/(4mN)^{1/2} = kv_A,\]

where \(m_i = 4(T_i/s^2)/3\) also is so-called "mass of phonons", \(T_i = T_i(0)\) - the 
effective temperature of the connected by the mutual drag system of "electron
Thus we may conclude that the mutual drag of carriers and phonons at external fields lead to the formation of compound particles ("quasi-particles") - "carriers dressed by phonons" with the joint drift velocity $u$.

In the first investigation [9] the considerations was made for the degenerate semiconductors and semimetals under the conditions of the propagation of weak electromagnetic waves. In particular in [8] was considered the propagation of weak electromagnetic waves on degenerate semiconductors with one type of carriers and was predicted the cyclotron resonance on the connected system of electron + phonon. But soon it was shown in [10] that this resonance does not observable because of the presence of impurities with the concentrations $N_i = n$ (where $n$ is the concentration of electrons). Also in [10] was shown that in pure semimetals it is necessary to take into account the presence of two type of carriers which drifted on the opposite directions at $H = 0$. The remarks about non-observably in [10] applies also to the uniform and non-uniform low frequency cyclotron resonance in degenerate semiconductors and semimetals with one type of carriers under the conditions of propagation strong electromagnetic waves considered in [6,7] and [11]. These questions was discussed in [3,7] and was shown that in intrinsic semiconductors and semimetals realized both uniform and non-uniform cyclotron resonance on quasi-particle "hole + phonon". In [3,7] also was shown that the such type of resonance realized on non-degenerate impurity and intrinsic semiconductors and discussed the question about their observably.

## 2 General

In present paper the connected system of kinetic equations for interacting system of electrons, positrons and photons in external high electric $E$ and arbitrary magnetic $H$ fields are solved. The non-equilibrium distribution functions of electrons, positrons and photons are founded by the taking into account of the arbitrary heating and mutual drag.

For the photons the general solution of non-stationary and non-uniform Boltzmann equations was founded. The cases of week ($\omega_H^\pm \tau_c \ll 1$, classically high ($\omega_H^\pm \tau_c \gg 1$, and quantizing ($\hbar \omega_H^\pm \gg T, T_c$) high magnetic fields are considered. Here $T$- is the initial temperature of equilibrium system (at the $t = 0$, before the external fields is applied), $T_c(E, H)$ -is the temperature of heated electrons and positrons, $\omega_H^\pm$ - is their cyclotron frequencies, $\tau_c^{-1} = \nu_c$ the relaxation frequencies of electrons and positrons (the photon production by the annihilation electron-positron’s pair or by the scattering of electrons and positrons by photons). $c = e, p$ means electrons and positrons, accordingly.

In the absence of or in a weak magnetic fields the inter-carrier collisions frequencies $\nu_{ee}$ and $\nu_{pp}$ assumed much more than others, and that is why the
isotropic parts of the distribution functions of carriers assumed to be equilibrium one, with effective temperatures of carriers $T_c = T_{e,p}(E, H)$. This approximation corresponds to the case of high concentration of carriers $n > n_k$.

If the external field is a field of strong electromagnetic wave, then it is necessary to fulfil of the condition:

$$\omega \gg \nu^\pm_c$$

(1)

$\nu^\pm_c$ - is the collusion frequencies of carriers for energy transfer to scatters, $\omega$ - is the frequency of electromagnetic wave.

Under the conditions (1) the isotropic parts of carriers distribution functions at zero approximation by $\nu^\pm_c/\omega$ do not depend on time directly. By the direct solution of quantum kinetic equations in common case for the arbitrary spherical symmetric dispersion law of carriers, it was shown that at quantizing and classically high magnetic fields the stationary distribution functions of carriers, satisfying the boundary conditions, $F^\pm(\epsilon)|_{\epsilon \to \infty} = 0$ has the form (for the arbitrary quantities of their concentrations):

$$F^\pm(\epsilon) = \left\{ e^{-1} \exp \left( \int \frac{d\epsilon'}{T_c(\epsilon', t)} + 1 \right) \right\}^{-1}$$

(2)

There $T_c(\epsilon, t) = A(\epsilon, t)/B(\epsilon)$ - the temperature of carriers which have occupied the energetic level $\epsilon$,

$$A(\epsilon) = (2\pi/\hbar) \sum_{\alpha\beta q} C^2_{\alpha\beta q} \cdot |I^2_{\alpha\beta q}| \cdot (\hbar \omega^*_q)^2 N(q, t) \delta(\epsilon_\beta - \epsilon_\alpha - \hbar \omega_q) \cdot \delta(\epsilon_\alpha - \epsilon)$$

$$B(\epsilon) = (2\pi/\hbar) \sum_{\alpha\beta q} C^2_{\alpha\beta q} \cdot |I^2_{\alpha\beta q}| \cdot \hbar \omega_q \delta(\epsilon_\beta - \epsilon_\alpha - \hbar \omega_q) \cdot \delta(\epsilon_\alpha - \epsilon) \cdot \omega^*_H = \hbar \omega_q - \vec{V} \cdot \vec{q}$$

$C_{\alpha\beta q}$ - being the constant of interaction and $I_{\alpha\beta}$ - is a matrix elements for the transition from state $\alpha$ to $\beta$ and back (reverse).

For the arbitrary degree of quantization we have:

$$F^\pm(\epsilon) = \left\{ 1 + \exp \left[ (\epsilon - \zeta(E, H)/T_c) \right] \right\}^{-1}$$

$$T_c = T_1 \left\{ 1 + \left( \frac{V^\pm}{u} - 1 \right) \frac{1}{2(\varphi_1 - 1)} \right\}$$

(3)

$$\varphi_1 = \left[ 1 - \frac{u^2}{c^2} \right]^{-1/2}$$

At the classical region of strong magnetic field we have:
\[ T_c = T_i \left\{ 1 + \frac{1}{3} \left( \frac{V^\pm}{c} \right)^2 + \left[ 1 - \frac{V^\pm}{u} \right] (\varphi_2 - 1) \right\}, \quad \varphi_2 = \frac{c}{2u} \ln \left| \frac{c + u}{c - u} \right| \]

(3')

Here \( V^\pm = cE/H \) is the Hall's drift velocity of carriers. It was shown that for all considered cases the solution of non-stationary kinetic equation for the photons is:

\[
N(\vec{q}, t) = \left\{ N(\vec{q}, \vec{r} - \vec{u}_o t, 0) + \beta \int_0^t N(q, \tau') \exp \left( - \int_0^{\tau'} \gamma_q (\tau') d\tau' \right) \right\} \times
\]

\[
\times \exp \left[ \int_0^t \gamma_q (\tau) d\tau \right]
\]

(4)

Where \( N(\vec{q}, \vec{r} - \vec{u}_o t, 0) \) the distribution function of photons in the absence of electric and magnetic fields (at \( t = 0 \)), which in the case of space uniformity is equilibrium Plank's function at the temperature \( T \). The increasing increment of photons is

\[
\gamma_q = \beta \left[ \frac{\vec{u} \cdot \vec{q}}{\hbar \omega_q} - 1 \right]
\]

(5)

\( \beta = (\beta_e + \beta_p + \beta_{ph} + \beta) \) is a total collisions frequency of photons with electrons \( (e) \), positrons \( (p) \) (including the photon decay to electron-positron pair), photons \( (ph) \) and boundaries \( (b) \) of region occupied by the system, if such one exists.

\[
\vec{u} (t) = \sum \vec{u}^\pm (t) = \frac{\beta}{\beta_e} \vec{V}^- (t) + \frac{\beta_p}{\beta} \vec{V}^+ (t)
\]

(6)

\( \vec{V}^\pm (t) \) is average drift velocity of carriers, \( \vec{u}^- (t) \) - the drift velocity of connected by the mutual drag system of "electron + positrons" and \( \vec{u}^+ (t) \) is the same for the "positron + photons".

In the common case, when the heating of carriers was realized by the field of strong electromagnetic wave \( \vec{E} = \vec{E}_0 e^{-i\omega t} + \vec{E}_0^* e^{+i\omega t}, V^\pm (t) = V^\pm \cos \omega t \) we have:

\[
N(\vec{q}, t) = \left\{ N(q, o) + \beta \int_0^t d\tau N(q, \tau) \exp \left[ \beta \left( \frac{\vec{u} \cdot \vec{q}}{\hbar \omega_q} \sin \omega \tau \right) \right] \right\} \times
\]
\[
\exp \left\{ -\beta \left[ t - \frac{\vec{u} \cdot \vec{q} \sin \omega t}{\hbar \omega} \right] \right\} \tag{7}
\]

In the case of constant external electric field (\(\omega \to 0\)) we have:

\[
N(q,t) = \left\{ \frac{N(q,0) - N(q,T_i)}{1 - \frac{\vec{u} \cdot \vec{q}}{\hbar \omega}} \right\} \exp \left\{ \beta \left[ \frac{\vec{u} \cdot \vec{q}}{\hbar \omega} - 1 \right] t \right\} + \frac{N(q,T_i)}{1 - \frac{\vec{u} \cdot \vec{q}}{\hbar \omega}} \tag{8}
\]

Here \(T_i = (\beta_c/\beta) T_c + (\beta_{ph}/\beta) T_{ph} + (\beta_b/\beta) T_b\) is the temperature of the coupled by the mutual drag system of heated complexes of carrier and photons.

We have still considered the case when the initial state of photons (at \(t = 0\)) was assumed to be equilibrium state without distinguished direction. If the part of initial distribution of photons has directional drift (the photons stream), then the kinetic equation for the photons has the form:

\[
\frac{\partial N(q,\vec{r},t)}{\partial t} + \frac{\partial N(q,\vec{r},t)}{\partial \vec{r}} \cdot d\vec{r} = \beta \left\{ -N(q,t) \left( 1 - \frac{\vec{u} \cdot \vec{q}}{\hbar \omega} \right) \right\} + N_i(q,T_i) \tag{9}
\]

By the single substitution \(t' = t\) and \(\vec{r}' = \vec{r} - \vec{u}_o t\) the solution (10) may be transformed into the form:

\[
N(q,\vec{r},t) = \left\{ N(q,\vec{r} - \vec{u}_o t,0) + \beta N_i(q,T_i) \int_0^t \exp \left[ \beta \int_0^\tau \left( 1 - \frac{\vec{u} \cdot \vec{q}}{\hbar \omega} \right) d\tau' \right] d\tau \right\} \times \exp \left\{ -\beta \int_0^\tau \left( 1 - \frac{\vec{u} \cdot \vec{q}}{\hbar \omega} \right) d\tau \right\} \tag{9'}
\]

Thus it is seemed that the solution of the uniform equation for the photons (8) and non-uniform equation (9') have the same form corresponding to the different initial conditions. Therefore, if the initial distribution function of photons has the form of the drifted Plank distribution function \(N(q,\vec{r} - \vec{u}_o t,0)\) and if the external fields is uniform, then this non-uniformity has to be served with time and the drift at external field is to be added to them. Thus the equation (9') allows to consider processes of absorption or amplification of photons, introduced to the system from outside (initial stream of photons), and the generation of own photons of system in external fields. In principle it is the most common form of the initial distribution function, which is taking the chance for examination of the affirmation of the special theory of relativity about equivalency of all
inertial frames of reference. Really by the transition to the frame of reference drifting jointly with photons, as a result, we have the Plank’s equilibrium distribution function at the temperature $T$ in this frame of reference. In the other words, in the absence of external fields ($E = H = 0$) for the initial non-uniform system of photons (9) from kinetic equation we receive the uniform one, by the transition from one frame of reference to another but it is not means that the two frames of reference is equivalent.

In fact, by the transition from the frame of reference drifting jointly with the photons by the velocity $u_o = c \frac{\vec{q}}{q}$ to the frame of reference which in the rest which is equivalent to the transition from one internal frames of reference ($u = u_o$) to the other ($u = 0$) we receive $N(\vec{q}, \vec{r} - u_o t, 0) = N(q, 0) = N_o(q, T)$, for all moments of time, that is the solution (9’) transform to (8), but it is not means that this two frame of reference is equivalent. On the other words the demand of equivalency of the laws of physics in that two inertial frame of reference is equivalent to the demand of the equivalency the equilibrium Plank’s distribution function to the drifted Plank’s distribution function or to the demand of equivalency the laws of physics in the uniform and non-uniform cases (or spaces).

As one can see from (4), (8) and (9’) the general solution of non-stationary equation of photons have the stationary limit in the region of drift velocities \( \left( u \frac{\vec{q}}{\hbar \omega_q} \right) < 1 \)

$$\lim_{t \to \infty} N(q, t) = N(q) = N(q, T_i) \left( 1 - \frac{u q}{\hbar \omega_q} \right)$$ (10)

As it seems from equations (4), (8) and (9’) for the drift velocities \( \left( u \frac{\vec{q}}{\hbar \omega_q} \right) > 1 \) the distribution function of photons becomes exponentially grown by the time. It is accords to the generation of intrinsic photons by the increment of growth $\gamma_q$ and amplification of photons introduced to the system from outside (stream of photons) by the coefficient of amplification

$$\Gamma_q = \frac{\gamma_q}{c} = \beta \left( \frac{\vec{u} \frac{\vec{q}}{\hbar \omega_q} - 1}{\beta c} \right) = \beta \left[ \frac{\vec{u} c \cos a - 1}{c} \right]$$ (11)

$\alpha = \left( \vec{u} \cdot \vec{q} \right)$ - the angle between the drift velocity of connected by the mutual drag system "electron + photons" ("the dressed electron") or " positron + photons" ("the dressed positron") and momentum of photon. The expression for the electrical current of electrons and positrons at classically high external magnetic fields has the form:

In the case of the propagation of strong electromagnetic wave and at the presence of external magnetic field the current of electrons and positrons has the form:
\[ j_\pm = n e V^\pm, \quad V^\pm = \left\langle V^\pm (\epsilon) \right\rangle \] - is the averaged drift velocity of carriers. Here

\[ V^\pm (\epsilon) = \mp \frac{e \Omega_\pm(\epsilon)}{m_c} \left[ \frac{\epsilon}{\Omega_\pm(\epsilon)} \frac{\hbar \epsilon}{\hbar} \left( \frac{\epsilon}{\Omega_\pm(\epsilon)} \right)^2 \right] - \frac{\hbar}{\Omega_\pm^2 - (\omega_\pm)^2} \left( \frac{\epsilon}{\Omega_\pm} \right) H / H \]

(12)

In the case of \( \omega \to 0, \quad \vec{E} \parallel \vec{H} \) (or \( H = 0 \)):

\[ V^\pm (\langle \epsilon \rangle) = \frac{e}{m_c \nu_{ph} (\langle \epsilon \rangle, \nu)} \cdot \beta_{ph,b} = \frac{e \vec{E}}{m (T_i, \nu) \cdot \beta_{ph,b}} \]  

(13)

Here \( m = m_c \cdot \nu_{ph} (\langle \epsilon \rangle, \nu) / \beta_c \) - the mass of connected by the mutual drag system of carriers and photons and \( \beta_{ph,b} = \beta_{ph} + \beta_b \).

Really, the interacting system of electrons, positrons and photons at the external high electromagnetic and the classically high or the quantizing magnetic fields under the conditions of their heating, mutual drags and at the stationary conditions \( \left( \frac{\epsilon \cdot \nu}{\hbar \omega_q} \right) < 1 \) has the cyclotron resonance with the frequencies

\[ \omega_\pm = \frac{eH}{(T_i/c^2) c} = \frac{eH}{m(T_i)c} \]  

(14)

As it seems from the equation (12) the resonance is taking place on frequencies of electromagnetic wave less than the collision frequencies of photons with carriers. The width of the resonance lines defined by the expression \( \gamma = (3/2) \left[ \omega^2 / \beta_c + \beta_{ph} + \beta_b \right] \).

In the other words, because of the mutual drag, the electrons and positrons turn into the compound particles (into the coupled system of "electron + photons" and "positrons + photons" i.e. so called "dressed" by the photons "quasi-electron" or "quasi-positron" with the effective mass \( m(T_i) \)). In fact, we receive the quasi-particle with the electron’s or positrons charge and the photons mass:

\[ m(T_i) = m(E, H) = T_i/c^2 \text{ or } E = T_i = m(T_i)c^2 \]  

(15)

Since \( T_i \) and \( T \) means the average kinetic energy, then from the equation (10), (11) and (14) we receive that the, so-called "velocity of light" in vacuum "c" is the average velocity of photons in the equilibrium or stationary state with the temperatures \( T \). The "dressing" of electrons and positrons in quantum electrodynamics was connected with the virtual absorption and emission of photons by the electrons and positrons, which is occupied the given level of energy, i.e. with the finiteness of the lifetime of electrons and positrons or the natural width of the given energetic level. For the interacting system of electrons, holes and phonons in semiconductors, semimetals and gaseous plasmas the analogous problem was solved in [1-5].
As it seems from (4), (8), (9') and (10) at the external electric and magnetic fields under the stationary conditions the relativistic factor enters to the distribution function of photons in first order in the form \([1 - \frac{u \cdot q}{\hbar \omega_q}]^{-1}\), instead of the form \([1 - \frac{v^2}{c^2}]^{-1/2}\) in relativistic electrodynamics. This is connected with the violation of \(T\)-symmetry \((t \rightarrow -t)\) of equations in electrodynamics and, in common dynamics at the external fields. In this case the uniformity of the space and as a result the law of the conservation of momentum is violated too. Since the external fields acts constantly but not instantaneously i.e. we have the motion with acceleration and the oscillatory regime is absent. The substitution \(t \rightarrow -t\) do not simply lead to substitution \(\rightarrow v\rightarrow -\rightarrow v\), because of the motions along and opposite of field direction are differs and do not compensate each other.

The relativistic factor of the type \([1 - \frac{v^2}{c^2}]^{-1}\) may appears only at the absence of external field in equilibrium or stationary conditions, by the using the isotropic part of the distribution function of photons. Factually, by the separation of the stationary distribution function of photons (10) to the isotropic and anisotropy parts we have:

\[
N(q) = N_s(q) + N_\alpha(q) = N(q, T_i) \left[1 - \frac{u^2}{c^2} \cos^2 a\right]^{-1} + N(q, T_i) \frac{u}{c} \cos \alpha \left[1 - \frac{u^2}{c^2} \cos^2 a\right]^{-1}
\]

(16)

Since as a result of the mutual drag the carriers and photons form the connected system (complex) with the common drift velocity, then under the conditions of strong (full) mutual drag \(\alpha = 0\) or \(\pi\) and we received:

\[
N_s(q) = N(q, T_i) \left[1 - \frac{u^2}{c^2}\right]^{-1}; \quad N_\alpha(q) = \left(\frac{u}{c} \cos \alpha\right) N(q, T_i) \left[1 - \frac{u^2}{c^2}\right]^{-1}
\]

(17)

In the absence of external electric and magnetic fields, in common case \(u = u_o = \text{const}\) and we have:

\[
\tilde{N}(\rightarrow q, \rightarrow u_o) = N(\rightarrow q, \rightarrow r - \rightarrow u_o \cdot t, 0) = \left\{\exp\left(\frac{\hbar \omega_q}{T}\right) - 1\right\}^{-1}
\]

(18)

\(\hbar \omega_q = \hbar \omega_q - \rightarrow u_o \rightarrow q\). By the transition to the frame of reference drifting together with photons we can received (16) the equilibrium Plank's distribution function with the temperature \(T\). Let us discuss the main question now: may the presence of the relativistic factor of first or secondary order lead to any singularities in physical phenomena or quantities? As it seems from the non-stationary solution for the distribution function of photons (8) or (9') the Lorenz-Einstein theory corresponds to uniform (equilibrium) case and must satisfy the stationary condition \(v/c < 1\)!

The case of \(v = c\) is not included to their theory and for
this reason the conclusions of the Einstein theory about equality the rest mass of photons to zero and $c$ - is the ultimate velocity of propagation of all types of interaction in nature do not have the real basis.

Really, from general solution of the non-stationary kinetic equation for the photons (8), by the dividing the exponent to the series near the point $\frac{\vec{u}\cdot \vec{q}}{\hbar \omega_q} = 1$ we have

$$N(q, t) = \left\{ N_o(q, T) + \frac{\beta N(q, T_i)}{\gamma_q} \right\} \left\{ 1 + \gamma_q t + \frac{1}{2} (\gamma_q t)^2 + ... \right\} - \frac{\beta N(q, T_i)}{\gamma_q} =$$

$$= \left\{ N_o(q, T)(1 + \gamma_q t) + N(q, T_i)\beta t \right\} + \frac{1}{2} \left\{ N_o(q, T)(\gamma_q t)^2 + \beta \gamma_q N(q, T_i)t^2 \right\}$$

(19)

In the point $\gamma_q = 0$ we have

$$N(q, 0) = \lim_{\gamma_q \to 0} N(q, t) = N_o(q, t) + N(q, T_i)\beta t$$

(20)

As it is shown from this expression at the point $\frac{\vec{u}\cdot \vec{q}}{\hbar \omega_q} = 1$, i.e. at the point $u = c$ the distribution function of photons is non-stationary and grows linearly by the time. What about of the singularity it is abbreviated clearly!

Since the Einstein theory is a stationary one it did not applied to the non-stationary conditions, namely to the region of the drift velocities $v = c$ or $u = c$. For the drift velocities $v \geq c$ or $u \geq c$ the theory must be non-stationary. The Einstein theory is a one mode theory and that is why must be received from the many particle (or many mode) theory by the limiting transition to the one mode case. The effect of connection charged carriers and photons as a result of their mutual drag is a common phenomenon. It is a reaction of the system on action of external fields for the conservation the stationary state of system (the analog of "self-conservation" in biology). Thus we are found the "dressing" mechanism of charge carriers used earlier in quantum electrodynamics.

### 3 Conclusions

As a result of analysis the phenomena of connected system of charge carriers and photons by the using of equations (4), (7) - (10) and (15) we receive the following conclusions:

1. As it seems from non-stationary distribution function of photons the Lorenz-Einstein theory corresponds to space uniform (equilibrium) case and must satisfy the stationary condition $v < c$! The case of $v = c$ is not included in their theory. In the point $u = c$ (i.e. $\gamma_q = 0$) the distribution function of photons (18) is non-stationary do not content any singularity and grows linearly by the time.
For this reason the conclusions of Einstein theory that the rest mass of photons is equal to zero and $c$ - is the ultimate velocity of propagation of all types of interactions in nature do not have the real basis.

2. Since the Einstein theory was a one mode theory and that is why must be received from the many body (mode) theory by the limiting transition to the one mode case at $v < c$. For the $v > c$ or $(u > c)$ the theory must be nonstationary. As we say the mutual drag lead to the formation the ”quasi-particles” - the electron or positron ”dressed by photons”. The average energy in stationary state $u < c$ for the one mode case is:

$$\langle \epsilon \rangle = \langle h\omega \rangle \langle N_i(q, T_i) \rangle = \frac{Ti \langle N(\omega, Ti) \rangle}{1 - u^2/c^2} =$$

$$= \frac{T \langle N(\omega, Ti) \rangle Ti}{1 - u^2/c^2} = \frac{M_o c^2}{1 - u^2/c^2} \left( \frac{Ti}{T} \right)^2$$  (21)

The mass of the heated photons for one mode:

$$M_i = \frac{M_o}{1 - u^2/c^2} \left( \frac{Ti}{T} \right)^2$$

The mass of one heated photon:

$$m = \frac{M_i}{\langle N(\omega, T_i) \rangle} = m_o \frac{Ti}{T} \left( 1 - \frac{u^2}{c^2} \right)^{-1} \quad (21')$$

At the absence of heating

$$\langle \epsilon \rangle = M^2 = \langle N_o(\omega, T) \rangle \frac{T}{1 - u^2/c^2} = M_o c^2 \frac{T}{1 - u^2/c^2} =$$

$$= m_o c^2 \langle N_o(\omega, T) \rangle \frac{T}{1 - u^2/c^2}, m = \frac{m_o}{1 - u^2/c^2},$$ \quad (22)

$m_o = M_o/\langle N_o(\omega, T) \rangle = T/c^2$ is the rest mass of photon, i.e. the mass of photon in frame of reference which drifted jointly with photons at the temperature $T$, $\langle N \rangle$ is the concentration of photons for one mode.

3. As it seems from (19) at high electric and magnetic fields for the drift velocities $u < c$ the energy (or the mass) of photons for one mode grows as a result of the mutual drag, as well as the heating of the carriers and photons.

4. As it seems from (4)-(10) at the external electric and magnetic fields the relativistic factor enters to the expressions of the distribution function and other physical quantities in first order in the form $(1 - u^2/c^2)^{-1}$, instead the $(1 - v^2/c^2)^{-1/2}$ in Einstein theory. This is together with the conclusions 1 and 2 is solve the main problem of super-luminal particles named -tachyons, because of in our theory the imaginarytity of mass of tachyons is liquidated.
5. There is the opinion that the original conception about tachyons, as individual particles such as the electrons, protons and etc. is not correct and the tachyons in such understanding is absent [12]. Our investigations shows that the ordinary particles such as the electrons, positrons and also photons may stand a super-luminal in high external fields under the conditions of mutual drag. Also there are the opinion that the tachyons as an elementary excitations (quasi-particles) have the wide - spread in complex systems which is lose the stability and made the phase transition to the stable state [ibid] . In origin the tachyons in general was considered only in amplifying mediums [13-16]. As it seems from our investigations factually for the drift velocities more than the velocity of light the super-luminal particles are generate or are amplify the electromagnetic waves (photons) and the super-luminal particles are placed on the regime of generation or amplification independently from on type of medium (see also [17]). As it will be shown in a special report in general all elementary excitations including so- called " elementary particles " are the quasi-particles.

6. In the point of \( u = c \) the angle \( \alpha \) between the \( \vec{u} \) and \( \vec{q} \) is equal to \( \pi/2 \) and we have the condition when the electromagnetic wave becomes a free and is emitted. Thus the point of \( u = c \) is the point of transition of system from absorption regime to the regime of emission of electromagnetic waves (photons).

7. It is shown that the relativistic expression for the deceleration of time really taking place for the relaxation time of carriers on photons, for the life-time of carriers and also for the period of electromagnetic oscillations. Factually, in dynamics and electrodynamics the time is enter as a parameter, but not as a free coordinate and for this reason the Einstein relation is impossible to apply to the time.

Since \( \tau_i = N_i(q, T_i) \) we have \( \tau_i \approx \tau_o \left( 1 - u^2/c^2 \right) (T/T_i); l = u\tau_i = l_o \left( 1 - u^2/c^2 \right) (T/T_i). \)
If \( T_i = T \) we have \( \tau_i \approx \tau_o \left( 1 - u^2/c^2 \right); l = l_o \left( 1 - u^2/c^2 \right). \)

8. It is shown that the so-called "velocity of light" in vacuum \( -c \), as well as the velocity of sound for phonons, is an averaged velocity of photons at the ground state.

9. As it seems from (4), (7), (8) and (10) at the point \( u = c \) the distribution function of photons is an isotropic one and the anisotropy part of photons distribution function at this point is equal to zero. It means that the ground and the stationary states of electromagnetic field is spherically symmetric (this question will be discussed in a special report). At the point \( u = c \) the stimulated absorption and emission are equal to each other and there are only spontaneous emission of photons.

10. It is shown that the demand for invariance of the Maxwell equations or the laws of physics in all inertial frames of reference is not correct. It is equivalent to the demand of invariance the lows of physics in the uniform and non-uniform spaces or to the demand of equivalency the lows of physics in cases of the presence and absence of external field (force).
11. It is shown that the presence of the second inertial frame of reference moving with the constant drift velocity relatively to first one may be a result of the presence of space non-uniformity or the non-uniform external field. Really in the uniform space because of the equivalency of all points of space it is impossible to get simultaneously two, or more inertial frame of reference with the different constant drift velocity relatively to each other. Because it will lead to the violation of the space uniformity, i.e. to the change of the distance $r_{12}$ between the initial points of that frames of reference ($r_{12} \neq \text{const.}$). In the uniform space for the conservation of the space uniformity during the motion it is necessary a motion of all points of the space with the same constant velocity (in the absence of the external field), or with the constant acceleration (in the presence of the uniform force). For the both cases the frames of reference, connected with the different points of the space, do not have the motion relatively to each other without the violation of the space uniformity or the uniformity of the external force. Since all points of the spaces in both cases are placed on the same conditions and are equivalent. In the second case for the reason that the force in the Newton’s second law is external one the system (or the space) must be opened. To choose two frames of reference moving with the constant drift velocity relatively to each other, it is necessary to have the space, which consists of two half-spaces. All points of first half-space are in rest or have the motion with the constant velocity $v$ and all points of second half-space are move with the constant acceleration. The first of them is inertial, but the second accelerates and for this reason the demand of equivalency of laws of physics in that two frames of reference is equivalent to the demand of the equivalency of first and second Newton’s laws. This demand is absurd, of course!

12. As it seems from (1) - (4) the demand of the equivalency of laws of physics in the all inertial frames of reference for the photons is equivalent to the demand about equivalency the Plank’s equilibrium distribution function to the drifted Plank’s distribution function.

13. It is shown that at the external electric fields $E < H$ the drift velocity of carriers $u < c$ and the energy received from external field is accumulated by the connection of carriers with photons, as a result of the mutual drag (as a result of the construction of structure by the mechanism of ”dressing of carriers with photons”) and stationary state is conserved. In this region of the drift velocities the absorption is more than the emission. Under the conditions $E > H$ i.e. at the drift velocities $u > c$ the generation and amplification is dominate and there are the exponential grown the number of photons by the time. The violation of the stationary state is begins from the point $u = c$ and from this point is begins the transition of the carriers” dressed by photons” to the following stationary state by the reactive emission of photons. In the region of drift velocities $u > c$ the anisotropy part of the photons distribution function is much more than the isotropic one. Thus in our investigation the mechanism of the transition of particles to the following stationary state is obtained.
14. It is shown that for the drifted velocities \( u > c \) so-called energy (or mass) for one mode are:

\[
\langle \epsilon \rangle = \left( \frac{T_i}{T} \right)^2 \cdot \frac{T}{u/c - 1} \left\{ [\exp (\gamma_q t) - 1] + \frac{T}{T_i} \exp (\gamma_q t) \right\} = M_o c^2 \frac{u/c - 1}{u/c - 1} \left\{ [\exp (\gamma_q t) - 1] + \frac{T}{T_i} \exp (\gamma_q t) \right\} \tag{23}
\]

or the mass for one mode:

\[
M = M_o \frac{1}{1 - u/c} \left\{ [\exp (\gamma_q t) - 1] + \frac{m_o}{m_i} \exp (\gamma_q t) \right\} \tag{23'}
\]

In the absence of heating

\[
M = M_o \frac{u/c - 1}{u/c - 1} [2 \exp (\gamma_q t) - 1] \approx \frac{2 M_o}{u/c - 1} \exp (\gamma_q t) \tag{24}
\]

As it seems from this equations the mass of photons for one mode in this region of drift velocities is \( u > c \) grows by the time exponentially.

The case considered by Einstein may be correspond to the case when from two choosing frame of reference the first was connected with the photons and drifted together with them and the second was connected with the charged carriers (electrons or positrons) drifted with constant velocity relatively to first one. Here the photons (electromagnetic field) is plays the role of media and the charged carriers drifted relatively to that media. Thus the system must consists of three subsystems. Factually, in electrodynamics the space (or the system) is consists from three half-space (or subsystems): the half-space of negatively charged carriers, half-space of positively charged carriers and the half-space (or space) of photons. For this reason the electrodynamics space is non-uniform initially, because of the point of space where is placed of negatively charge carrier do not equivalent to the point of space where is placed the positively charged carrier and both do not equivalent to the point where is placed the photon. The presence of the two type of charge lead to the presence of so-called Lorentz force. The condition of stationary of state is the equality of this force to zero \( F = 0 \) ! This condition corresponds to the annihilation of charge carriers with production of photons, i.e. production of free electromagnetic field without charges. It means that the space of photons (i.e. free electromagnetic field) can decay to the two half-spaces: the spaces of the negative and positive charges and also two half-spaces of negative and positive charges can product the space of photons (the electromagnetic space or media).

As it seems from our investigations considered by Lorentz and Einstein case corresponds to the case of the presence of weak external field when the heating of carriers and photons are absent and there are only their mutual drag. Also they was considered the case of one type of charged carriers. In the presence of mutual
drag of the electrons and photons the distribution function of photons $N(q)$ has the form of the displaced Plank’s function with the constant drift velocity and as a result with the renormalized frequency of emission $\omega_{em} = \omega_q - \frac{\vec{u} \cdot \vec{q}}{\hbar}$. For the drift velocities $u < c$ is decrease with the increasing of drift velocity $u$ because of the stationary function of photons has the form (18) or (10).

Thus in the second frame of reference charge carrier is emitted or absorbed photon with the frequency $\omega_{em}^* = \omega_{abs.} \left[1 - \frac{\vec{u} \cdot \vec{q}}{\hbar \omega_q}\right]$. In the one mode case the observed frequency $\omega_{abs} = \tilde{\omega} = \frac{T_i}{\hbar}$. In the other word

$$\omega_{abs} = \omega_{em} \left(1 - \frac{u}{c} \cos \alpha \right)^{-1} \text{ or } \lambda_{abs} = \lambda_{em} \left(1 - \frac{u}{c} \cos \alpha \right)$$

For the case when the both frames of reference assumed to be inertial one, i.e. to move along the one line (along the $x$-axis) $\cos \alpha = 1$ and we have

$$\omega_{abs} = \omega_{em} \left(1 - \frac{u}{c} \right)^{-1} \text{ or } \lambda_{abs} = \lambda_{em} \left(1 - \frac{u}{c} \right)$$

As it seems from this equation the Doppler effect is also a result of the mutual drag of carriers and photons. Factualy the source of emission (charge carrier) drifts relatively to frame of reference connected with the photon (observer) with the drift velocity $\vec{u}$. By the increasing of drift velocity $\vec{u}$ the distance between the source and the detector are increased too and as a result the observed frequency of photons is increased or the wavelength is decreased. In the opposite case the wavelength is increased. In the region of $u < c$ the source (the charge carrier) moves slowly than the detector (photon) and as a result the distance between them is decreased and the wavelength of observed photons (light) is increased. Thus the mutual drag of electrons and photons in the region $u < c$ lead to decreasing the frequency of emission or absorption (see "Low frequency cyclotron resonance for the phonons" [2,5,9]). It means that the frequency of observed light (photons) is increased.

15. As it seems from the present consideration the so-called relativistic phenomena and the Doppler effect is a same ones and are a result of the mutual drag of interacting system of carriers and photons at external field. The case was considered by Lorentz and Einstein corresponds to the case, when the charge carriers are drifted at the electromagnetic field under the conditions of the mutual drag of carriers and photons in the absence of their heating by the field.

Distinction between the results of the theory of relativity and the Doppler Effect is connected with them, that the Doppler Effect is dealing with the total stationary distribution function but no only it’s isotropic path as in theory of relativity. In the other words the Doppler Effect is received as a result of taking into account the violation of the $T$-symmetry at the external field.
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