Problems connected with electrons trajectory in separated atom

Evgueni V. Kovarski

e-mail: ekovars@netscape.net

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Abstract

The time-dependent electromagnetic field can results both pair waves and pair particles. It can be for mathematical relations between two functions with identical argument and difference of phases equal to $\pi$. Two examples both the opportunity of phase synchronism for different frequencies of atom-field interaction with known abnormal dispersion of refraction and the possible trajectories for pair particles are considered.

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INTRODUCTION

At atom-field interaction frequency-time splitting of a spectral line of spontaneous radiation can occur due to given the dressed atom theory at high intensity of external field or for explained splitting each of two energy atomics levels to some subleveels at low intensity of external field as a result of quantum interference effect, as it was supposed and demonstrated with help of 3D pictures titled as Probability-Time-Frequency (PTF) manifolds \[1\]. On the other hand for such observable characteristics as the spontaneous radiation is possible to use the transformation from trigonometrical functions of probability of a finding a particle at a concrete energy level inside atom to the exponential characteristics in space outside of atom. The rate of emission for the quantum transition depend on the derivative of probability \(P(\tau)\)

\[
R = \int_{0}^{\infty} \gamma \cdot [\exp(-\gamma t)] \cdot (\dot{P}) \cdot dt
\]

The well known formula for the transition probability \(P(\tau)\) given in single frequency excitation of the two level atom is:

\[
P_1 = \left[\frac{4\Omega^2}{4\Omega^2 + \Delta\omega^2}\right] \sin^2\left(\frac{\tau}{2}\sqrt{\frac{4\Omega^2 + \Delta\omega^2}{4\Omega^2}}\right)
\]

where \(\Omega\) is the Rabi frequency and \(\Delta\omega = \omega_0 - \omega_1\), are the laser frequency detuning values. Then the procedure of finding the rate of the power absorption leads to the correspondent profile:

\[
R_1 = \frac{2\Omega^2\gamma}{\Delta\omega^2 + 4\Omega^2 + \gamma^2}
\]

At a denominator of the formula there are three members, one of which can be incorporated with other of two stayed members. In this case this formula can be compared with a standard structure of Lorentz profile, at which denominator always there are only two members. Therefore communication of two spaces both the atomic and the external are carried out except the amplitude in unique parameter known as a full width on half of maximum
(FWHM) of spectral line measured in a scale of frequencies or time. This FWHM for a Lorentz profile is designated as \((2\gamma)\). The connection between this size of FWHM and a damping constant of oscillator same designated, but describing losses of energy of a particle at interaction with other particles in environment is especially brightly shown for wide of FWHM spectral lines due to collisions with other atoms. It is much more difficult to explain such connection between FWHM and \((2\gamma)\) for isolated oscillator or for radiation from stopped atom by laser cooling. Despite of it isolated oscillator has spontaneous radiation and therefore is characterized by so-called natural width of a spectral line connected with the same \((2\gamma)\) as the damping constant from classical equation of oscillator. It is possible to tell that it is one of difficult examples when the classical performances need to be combined with the quantum, if to mean that the energy level can be split as in the dressed theory. If such splitting is not connected to a magnetic field, therefore does not exist rules of selection for optical transitions and then there is a question about that occurs with a particle on line interacted with EM field if it is with identical probability at different energy statuses of sub levels. The time of spontaneous emission \(t_S\) from upper energy level is well known:

\[
t_S = \frac{3\pi \hbar \epsilon_0 c^3}{\omega_0^3 d^2_{21}}
\]

(4)

The probability that an electron with life, having unknown time \((t)\), will leave the upper energy level, and its spontaneous radiation will fade with known constant \((\gamma^{-1})\) is defined by function

\[
G_1 = \gamma_S \cdot \exp (-\gamma_S \cdot t)
\]

(5)

The probability that the upper level will become empty with a known damping constant \((\gamma)\) during the unknown time of spontaneous radiation \((t_S)\) is:

\[
G_2 = \gamma \cdot \exp (-\gamma \cdot t_S)
\]

(6)

At definition of complete probability of time of life it is necessary to take into account both probabilities.
\[ G = G_1 \cdot G_2 = \frac{1}{t \cdot t_s} \cdot \exp \left[ - \frac{t^2 + t_s^2}{t \cdot t_s} \right] \] (7)

The lifetime \( t \) going from function \( G_2 \) is oversized the lifetime \( t_L = 2t_s \) from the first distribution \( G_1 \) due to the contribution of no radiative decay that is important for a separated atom.

Other classical example is under consideration of the phase and group speed of the waves interaction with a separated atom, because for only one wave of an external EM field, as against a single pulse mode or mode of several EM waves, the group speed of the single wave exist only as a mathematics value and therefore does not influence on phase speed, if of course is to consider reception of a single external wave from single external oscillator. It is well known that the dispersion of an index of refraction \( n(\omega) \) named as the abnormal refraction is in a vicinity of resonant frequency \( (\omega_0) \) at interaction of an electromagnetic wave (EM) with two levels atoms \( E = E_0 \cdot \cos(\omega \cdot t) \), where the wave number is \( k = \omega \cdot n / c_0 \), \( (E_0) \) is the amplitude of an external EM wave, \( (c_0) \) is the speed of the light in vacuum. Phase \( (v_f) \) and group \( (v_g) \) speeds of a wave involved for an explanation of this effect are defined by the known relations due to the wave number can be spread out in a number on degrees of frequency is in a vicinity of resonant frequency \( (\omega_0) \):

\[ v_f = \frac{c_0}{n(\omega)} = \frac{\omega}{k(\omega)} \] (8)

\[ v_g = \frac{1}{dk/d\omega} = \frac{c_0}{n + (\omega - \omega_0) \cdot (dn/d\omega)} \] (9)

On the other hand such single wave can be submitted from external space as a set waves and then the physical sense for application of group speed is kept for single wave. However it is possible to assume and return situation, when single external wave cooperates with set of particles having for example a parallel trajectories.
I. WHETHER THERE IS A PROBLEM OF AN ELECTRONS TRAJECTORY IN ATOM?

Last example can be served by application of mutual orientation of a trajectory of a particle and field. Because the phase speed \(v_f\) depends on \((\omega - \omega_0)\), therefore, in particular, for two separated EM waves with frequencies detuned symmetrical respect to the central frequency of quantum transition in atom, named as sidebands modes of EM field, as known, that is possible to supply different phase speeds of EM waves in same environment. Is possible spatially to divide these waves and to direct them towards each other. So, the atom placed in such field, will test action of different forces \(f_1, 2 = dp/dt\), where \(m\) is the mass of the particle, \(x\) is the displacement of the atom along the EM field.

When an atom is under perturbation of two symmetrical and coherent laser frequencies \([1]\), therefore the frequency detuning conditions for such bichromat laser waves are:

\[
E(\tau) = E_0 [\cos(\omega_1 \tau) + \cos(\omega_2 \tau)]
\]  

\[
\Delta \omega_2 = \omega_2 - \omega_0
\]

\[
\Delta \omega_1 = \omega_0 - \omega_1
\]

For the special perturbation of the upper energy level there are two symmetrical frequencies and we can use the relation:

\[
\Delta \omega_2 = \Delta \omega_1 = \Delta \omega
\]

The transition probability is:

\[
P_2 = \sin(\Omega \cdot \frac{\sin(\Delta \omega \tau)}{\Delta \omega})^2
\]

With Bessel functions the probability \(P_2\) can be written:

\[
P_2 = [2J_1(\rho) \sin(\Delta \omega \tau) + 2J_3(\rho) \sin(3\Delta \omega \tau) + 2J_5(\rho) \sin(5\Delta \omega \tau) + .]^2
\]
The rate of radiation $R_2$ can be obtained by the same way as above for a single frequency excitation. After some algebra with Bessel functions and by use the known relation

$$\sin [\sin \Theta] = 2 \cdot \sum_{k=0}^{\infty} J_{2k+1}(z) \cdot \sin [(2k+1) \cdot \Theta]$$

there are two presentations of the rate $R_2$:

$$R_2 = \frac{\gamma}{2} (\Delta \omega)^2 \sum \left[ 2J_{2k+2}(2\rho) \frac{(2n+2)^2}{(2n+2)^2 \Delta \omega^2 + \gamma^2} \right]$$

$$R_2 = \frac{\gamma}{2} (\Delta \omega)^2 \sum \left[ 2J_{2k+2}(2\rho) \frac{1}{\Delta \omega^2 + \left(\frac{\gamma}{2n+2}\right)^2} \right]$$

Here numbers ($k \neq 0$) worth at Bessel functions ($J_{2k}$) coincide with numbers ($2n + 2 = 2k$), where ($n = 0, 1, 2, ..$) There are series with Lorentzian profiles. If the condition for detuning is: $\Delta \omega \gg \gamma$, then the rate of the power absorption $R_2$ is simply:

$$R_2 = \frac{\Gamma}{2} [1 - J_0 (2\rho)],$$

Thus the trajectory of an atom plays the important role, because the atom can be stopped by sidebands method that results in known now results on cooling atoms. Contrary an atom can be accelerated.

Let us note, that is interesting to consider the problem of the movement of an electron within atom with the trajectory along and against a direction of a wave vector of the EM field, because with the rotation inside atom the electron can additional braking or acceleration. So both the trajectory of electrons within atom especially in a case of quantum transition and spatial orientation of a field inside atom are important too. In this work it is offered to discuss only some of these problems due to this question is connected with the important presence of a damping coefficient ($\gamma$) in equation of the oscillator and because such modes of movement should be shown in radiation of a driven charge.
The quantum mechanics does not recognize exact definition of coordinates or trajectory of movement. If the force in classical physics is defined as $f = \frac{dp}{dt}$, in the quantum mechanics it is $(F = -\partial U/\partial t)$, where $(U)$ represents known potential. At the same time potential depends on coordinate $(x)$, which by virtue of known uncertainty relation in the quantum mechanics cannot be defined. However, a wave function $(\psi)$ in the quantum mechanics describes wave with not observable characteristics as the "wave frequency" $(H/\hbar)$ and is presented through the operators of coordinate $(X)$ and moment $(\Lambda)$, because the hamiltonian $2H = X^2 + \Lambda^2$:

$$\psi(x, t) = \left[ \exp \left( -i \frac{H}{\hbar} t \right) \right] \cdot \psi(x, 0) \quad (21)$$

Application of the operators is connected with two linear spaces, one of which is the space of laboratory where classical physics is work and coordinate is measured as $x$:

$$X\psi = x\psi \quad (22)$$

$$\Lambda\psi = -i \cdot \hbar \frac{\partial \psi}{\partial x} \quad (23)$$

The information about space of an atom can be received only in space of classical physics named in this work as the space of laboratory where for the known classical model of the oscillator the exam of the differential equation gives infinite on size value of displacement $(x)$ of the oscillator for both conditions the absence of the damping constant $(\gamma)$ and the exact resonance condition $(\omega = \omega_0)$:

$$\ddot{x} + 2\gamma \dot{x} + \omega_0^2 x = \frac{e}{2m} \cdot E_0 \cdot [\exp(\omega t) + \exp(-\omega t)] \quad (24)$$

$$x = \left[ \frac{e}{2m} \cdot \frac{E_0^2}{\omega_0^2 - \omega^2 + 2\gamma \omega} \right] + c.c. \quad (25)$$

Therefore it is obvious, that it is simultaneously impossible to simulate both conditions $(\omega = \omega_0)$ and $(\gamma = 0)$. Despite of it, it is possible to explain increase of displacement up to infinite size by display of the appeared acceleration. Really, the well known equation of a
clasical oscillator can be considered as a threshold condition at balance of several acceleration mechanisms for one connected electron. When the frequency of a field comes nearer to resonant frequency, then in this vicinity of frequencies or in the appropriate vicinity of time in system necessarily there should be an the damping, differently irrespective of energy of an electromagnetic field oscillations will simply be stopped when the electron becomes free, because increase of displacement up to infinite size.

Therefore there is a vicinity of time, when there are processes with several types of the damping mechanisms braking the electron. From known observable processes of these mechanisms, connected to presence, first of all, it is necessary to allocate the absorption and both spontaneous and compelled radiation. The important problem for one atom is the understanding of a nature of the spontaneous radiation damping constant. This problem concerns to a question on so-called optical friction and is general for the classical and quantum approach, as is connected that the damping is present at processes, which are not for separately taken atom, because there is no interaction with environment.

In the quantum mechanics the damping ($\gamma$) is entered in the equations provided that the electron already is at the exited level, and the field at this moment has no energy or is switched simply off like a case for a short pulse of a EM field. The presence of the damping is entered in the assumption, that probability of a finding atom in the exited status is. In case of unlimited quantity of oscillators, the system of the equations results for complete probability of spontaneous transition from the exited status. Thus the damping has the imaginary part and gives the amendment on displacement of own frequency, neglecting with which, however, it is possible to receive, that is defined by summation on all radiated quantum.

The important note is about the time as the complex number, which has not only size opposite to the frequency of an external field, but also size, opposite to the complex damping coefficient.

The connection between a spectral contour for probability and its FWHM is determined as well as by Lorentz function with inunknown value of the amplitude:
\[ L = \text{const} \cdot \frac{\gamma}{\Delta \omega^2 + \gamma^2 / 4} \]  

Let’s note, that the size \( \Delta \omega = |\omega - \omega_0| \) is variable and depends on adjustment of frequency of an external field \( \omega \) in relation to resonant frequency of quantum transition \( \omega_0 \) in atom between two energy levels. Let’s consider the norm one of the two typical functions, which make refraction index:

\[ k_A = \text{const} \cdot \frac{b}{a^2 + b^2} \]  

\[ k_B = \text{const} \cdot \frac{a}{a^2 + b^2} \]

It is possible to fix in them one of two variable \( a \) or \( b \). The norm can be used in three cases

\[ \text{const} \cdot \int \frac{da}{a^2 + b^2} = \text{const} \cdot \left[ \frac{1}{b} \arctan \frac{a}{b} + C \right] \]  

\[ A \int \frac{dy}{y^2 + 1} = A \cdot \pi = 1 \]

\[ A \cdot \pi = \int \frac{\sin^2(A \cdot y)}{y^2} \cdot dy \]

Anyone here is taken variable \( y \) and constants \( A \) and a free constant \( C \). It is clear, that it is possible to solve this system of the equations and to receive a number of the decisions, instead of one known \( y \).

Considering only one analytical function of complex variable \( z \) on a complex plane one can observe the power numbers \( q \):

\[ f(z) = \frac{1}{z^2 + 1} \]

In a circle \( z < 1 \), except for points \( z \neq i \), this function is an indefinitely decreasing geometrical progression with the radius of convergence \( r = 1 \):

\[ f(z) = \sum_{q=0}^{\infty} (-1)^q \cdot z^{2q} \]
In the other circle $|z - 1| < \sqrt{2}$, the radius of convergence ($r = \sqrt{2}$):

$$f(z) = \sum_{q=0}^{\infty} (-1)^q \cdot \frac{\sin(q + 1) \cdot \pi}{2^{q+1}} \cdot (z - 1)^q$$  \hspace{2cm} (34)

Therefore any quantum process observable in space of laboratory and described by the
formula passes through a number ($q \neq n_0$), where ($n_0$) is the main quantum number of
discrete energy levels. Consequently the picture of energy levels distribution in the space
of laboratory should correspond to this picture. It is possible to try to show importance
of distinction of performances about the main quantum number in different spaces on the
following example which is connected with classical parameter of refraction.

The direct transition from consideration of one atom to consideration of environment
consisting many ($N$) atoms and back requires a physical explanation of applicability for
separated atom ($N = 1$) not only concept of the damping constant, but also such concepts
as a parameter of refraction ($n$) or permeability ($\epsilon$). As is known, the polarization of
environment ($P$) is defined by the dipole moment ($d = e \cdot x$). On the other hand, the
polarization is defined by a susceptibility ($\alpha$) and electrical component of an electromagnetic
field ($E$):

$$P = N \cdot \alpha \cdot E = N \cdot e \cdot x = N \cdot d$$  \hspace{2cm} (35)

$$\epsilon = 1 + 4 \pi \cdot \alpha$$  \hspace{2cm} (36)

$$n = \sqrt{\epsilon}$$  \hspace{2cm} (37)

However permeability ($\epsilon$) and parameter of refraction ($n$) can not be simply transferred from
space of environment into the space of separate atom. In this work is possible to assume,
that there are features of structure of atom, which are shown that the connected electron
in atom and the free electron in space of laboratory are the same particle which are taking
place in different spaces. Therefore they can have differences in such characteristics, as a
charge ($e$) and the mass ($m$), because they have differences on dynamics of the movement
driven by EM field. The space of separate atom can have especial structure, in which the mass and the charges of the connected electron interacted with a EM field differ among themselves. Thus connected electrons with a negative charge in different atoms are considered taking place in different spaces, and free electrons with a negative charge leaving of energy limits of different atoms in space of laboratory are considered identical (standard electron). The change of particles mass ($m$) during movement should result in the certain conformity between complete energy of a particle and energy of the appropriate quantum transition. It is natural to assume, that the electromagnetic wave crosses set of spaces with different phase speed in each of them. Let’s name as resonant spaces such spaces, which are connected among themselves by any interaction to occurrence of a particle or information electromagnetic field. As an information electromagnetic field we shall name such electromagnetic field, which satisfies with the Maxwell equations and bears in the characteristics the information on investigated space. Let’s assume, that the resonant spaces having, at least, linear communication between one vector in one space with other vectors in the other space cooperate only. Let’s assume, that the birth of an electromagnetic field occurs on border of resonant spaces. The communication of two linear spaces of laboratory and atom is carried out by conformity between dependence of amplitude of a field on time and frequency in one space and in the another space with dependence of probability of finding electron at a energy level from time and frequency. Factor of proportionality defines a time scale in each space, i.e. the frequency of a EM field ($\omega$) and Rabi frequency ($\Omega$):

$$\Omega = \frac{d_{12} \cdot E}{\hbar}$$

(38)

where the dipole matrix element is ($d_{12} = e \cdot x_{12}$). It is possible to assume, that the vectors ($\vec{d}$) and ($\vec{x}$) characterize the space not as linearly dependent pair vectors, and as linear - independent pair vectors, therefore is possible to write down:

$$\vec{e} = e_1 \cdot \vec{d} + e_2 \cdot \vec{x}$$

(39)

Thus, the charge ($e$) of the connected electron is a vector ($\vec{e}$). This vector has projections to the allocated directions and, hence, brings in charging symmetry to space of atom. Therefore,
the application of the classical physical characteristics such as \((n), (\varepsilon)\) for separate atom is possible.

Assuming, that trajectory of an electron with speed \((V)\) is the circle, in which centre is nucleus, is necessary to return to a hypothesis of Bohr and De Broglie. On one orbit with length \((2\pi R)\), where radius \((R)\) is defined by:

\[
R = \frac{n_0 \cdot \hbar}{m \cdot V},
\]

is possible to lay an integer of lengths of waves \((\lambda \cdot n_0)\), where \((\lambda)\) is characterizes a wave nature of a material particle and \((n_0)\) is the main quantum number:

\[
\frac{\lambda}{n_0} = \frac{h}{m \cdot V}.
\]

On the other hand the same radius \((R)\) of an orbit can be determined from known relation:

\[
\frac{1}{8\pi\varepsilon_0} \cdot \frac{e^2}{R} = \frac{m \cdot V^2}{2}.
\]

One can to observe that the charge has the same vector nature that the velocity. Let’s copy the formula in view of a known ratio \((\lambda \cdot \nu = c_0)\), where the frequency is \((2\pi\nu = \omega)\), the speed of light \((c_0)\) is connected to phase speed of electrons wave through \((c_0 = v_f \cdot n)\), where \((n)\) - is a parameter of refraction.

\[
n = \frac{\hbar \omega}{m \cdot v_f \cdot V} \cdot n_0
\]

Thus, the parameter of refraction \((n)\) of an atom should be discrete size due to the main quantum number.

Let’s return to the decision of the classical equation of oscillator. It is possible to notice what exactly from here follows, that the permeability \((\varepsilon)\) is complex number. For this reason the parameter of refraction \((n = \sqrt{\varepsilon})\) is defined by a root of the second degree from complex number. However parameter of refraction defines a phase speed of an electrons wave. It is easy to show, that this phase speed is split on two waves distinguished on a phase on number \((\pi)\). This implies, that the main quantum number \((n_0)\) also can result in processes with the same phase displacement.
In physics some cases are known, when the difference of phases is equal to \((\pi)\). First it is shown at reflection of a EM wave. Secondly it is possible to search for such difference in phases at display of linear polarization of a wave. In third, such difference exists between positive and negative parts of periodic sine wave function.

II. POSSIBLE PAIR PROCESSES FOR WAVES AND PARTICLES

Let’s consider as an example probable reaction of an atom space to action of an external field. For this purpose we shall lead analogy between space of an optical crystal and the two levels atom. Let external field has given, for example, ordinary linear polarization named as a \((o)\)-wave, which in turn, as is known, can be submitted consisting from both the right and the left rotating vectors of polarization. Such two vectors, opposite on rotation can be considered, as two waves having the identical module and arguments distinguished on number \(\pi\). On an entrance of a crystal such external \((o)\)-field is usually represented as two identical \((o)\)-waves having identical frequency \(\omega\) and two identical amplitudes. Actually by such consideration the one wave goes about two waves having the identical module and different arguments. As a result of interaction, a unusual \((e)\)-wave with the polarization revolved on corner of 90 degrees is left the crystal. As is known, there is such spatial direction inside a crystal, in which the so-called \((oo - e)\) interaction results in identical factors of a parameter of refraction \(n_o(\omega) = n_e(2\omega)\) on the frequency \(\omega\) for \((o)\)- wave and on the frequency \(2\omega\) for \((e)\) -wave for known procedure of the second harmonic generation (SHG). Both fields are external in relation to space of a crystal, as their characteristics are measured in space of classical physics named as a space of laboratory. Thus, the phase synchronism of speeds \(v_f = c_o/n\) is a reaction of interaction of two spaces.

In gas environment of atoms the reaction of interaction both spaces the laboratory space and the space of atoms shown as similar SHG of \(2\omega\) should not essentially differ from reaction by the space of a crystal. Near to a line of absorption always there is an opportunity of a choice of two frequencies with an identical parameter of refraction due to the known
abnormal dependence of the refraction parameter. In the specific case frequencies can be multiple, as SHG, but the square-law dependence for low intensity external EM field of SHG intensity completely not necessarily should be observed. Thus it is necessary to distinguish, that at such low intensities the SHG in atomic environment differs from known process of the two photon absorption within an atom with the subsequent radiation. Generally is possible to think that at high intensities the multi photons generation of radiation differs from multi photons of absorption with the subsequent radiation, because can occur at conditions when the determining factor is the dependence \( n(\omega) \) near to a line of resonant absorption.

External in relation to atom and periodically time-dependent electromagnetic (EM) field \( E = E_0 \cos \omega \cdot t \) in space of laboratory is usually represented as analytical continuation of function valid variable \((\omega \cdot t)\) in complex area. In this work is paid attention to some features of such transition in a complex plane and back from the point of view of interpretation of physics of model connected to generation of an electromagnetic field.

When on some given piece \([a, b]\), where \( a = \omega_1 t_1 \) and \( b = \omega_2 t_2 \) of the valid real axis chosen along any direction of the space, that for length \([a, b]\), included in complex area, there is a unique function of the complex variable \( z = a + i \cdot b \). Accepting the same value that function real variable the electromagnetic field can be submitted on this piece by a converging sedate number in a known kind

\[
\sum c_n [\omega t - \omega_0 t_0]^n
\]  

(44)

From the mathematical point of view on definition of complex numbers follows, that one complex number can characterizes one physical value of pair real numbers with the established order of following of one real number behind another, where thus the only imaginary number \( z = i \cdot b \) is equivalent to \( a = 0 \). In particular, the EM field in space of laboratory is submitted as

\[
\frac{E_0}{2} [\exp (i \cdot \omega t) + \exp (-i \cdot \omega t)]
\]

(45)

Also this EM field incorporates the sum of two functions complex variable.
\[ \zeta_{1,2} = \exp(z_{1,2}) = \exp(a \pm i \cdot b) = \exp(\pm i \cdot \omega t) \]  

(46)

It means, that two variable \( z_{1,2} \) are correspond to a separately taken wave where the module of each is identical, but the arguments differ is familiar

\[ E_0 |\zeta| = E_0 \exp(a) = E_0 \]  

(47)

\[ \text{arg} \zeta_{1,2} = \pm b = \pm \omega t \]  

(48)

It is understandable, that interpretation of different marks of arguments of a field can serve performance about two vectors directed along the allocated direction of a numerical axis in opposite directions and distinguished on a corner equal \( \pi \).

It is known, that the loss of energy of an external field communicates, for example, with such effects, as effect of saturation in two-level atom (\( N_1 = N_2 \)) or with other known nonlinear effects occurring to a plenty connected electrons in different atoms at a large intensity of the external field. At the same time, in separately taken atom connected electron increases the energy only for the account (\( \hbar \omega \)). Therefore according to the quantum theory for excite separately taken oscillator it is enough to have vaguely weak on intensity external EM field.

Actually a threshold condition should exist as a ratio between losses of the electron on radiation \( \gamma_R \) and losses of a field on absorption \( \gamma_A \). At such understanding of processes the connected electron always radiates, including at the moment of transition to the exited energy level. For example, considering one-dimensional classical oscillator at the included external field, according to the theory of Einstein, it is necessary to exam processes of absorption, and also processes of the compelled and spontaneous radiation. These processes are characterized in known coefficients \( A_{21}, B_{21} \) and \( B_{12} \). In this connection, it is possible to write down the balance equation for various damping constants of classical oscillator, because the damping constant of spontaneous radiation \( \gamma_S \) is equal to \( A_{21} \):

\[ A_{21} + \frac{E_x^2}{8\pi} B_{21} = \frac{N_1}{N_2} \frac{E_x^2}{8\pi} B_{12} \]  

(49)
\[ \gamma_S + \gamma_B = \gamma_A \] (50)

The process of absorption is a resulting process and consequently the return size of \( \gamma_A \) corresponds to time of life \( \gamma_A = t_L^{-1} \). Therefore the parameter \( \gamma = \gamma_A \) should be present at the equation of the oscillator. Therefore becomes obvious, that the time of life should not be equaled of time spontaneous radiation \( \gamma_S^{-1} \).

If there is an absorption of energy of EM field in space of atom, this implies classical performance that the external field should cross a surface of atom under the laws by and large connected with the known laws of Fresnel for environments. Visible light absorbed by the majority of known atoms, does not test of diffraction on such small on the sizes object as atom. However, for shorter lengths of waves or for atoms with the large sizes occurring processes of reflection and (or) the absorption would result in occurrence of a diffraction shadow from atom. As the sizes of atom are small in comparison with length of a EM wave, such sizes allow to make transition to a limiting case of disappearance of objects in classical diffraction tasks, when the external field can be submitted on a complex plane as a spiral, including in a limiting case with a resulting vector along an imaginary axis. Agreeing with application of a known principle of Optics it is possible to assume, that the separate atom is a source of secondary waves. Apparently, the secondary waves in interpretation of this principle simply should mean the fact of an output from atom of pair waves with a difference of phases distinguished on number \( \pi \).

The EM wave can be presented as a continuous analytical function \( f(z) \) of complex variable \( z = x + i \cdot y \) with \( \dot{f} \neq 0 \), through partial derivative of functions \( (u) \) and \( (v) \):

\[
 f(z) = u(x, y) + i \cdot v(x, y) \] (51)

The continuity of function is carried out during each period, when there are limiting values \( \lim \{ [f(z)] = [f(z_0)] \} \) in a vicinity \( z \to z_0 \), when the inverse function is determined as

\[
 z = \phi\{f(z)\} \] (52)

\[
 \dot{f} = \frac{1}{\phi\{f(z)\}} \] (53)
\[
\begin{vmatrix}
  u_x & u_y \\
  v_x & v_y
\end{vmatrix} \neq 0
\] (54)

Therefore at return transition to the valid plane the function EM field as the function of complex variable can be presented as two functions valid variable \((u)\) and \((v)\).

For presentation it is possible to consider possible interpretation of occurrence of a usual periodic wave with constant amplitude \(E = E_o \cdot \sin(\omega t)\). Such recording for both electrical components of a field means that at increase of size of product of frequency at time there is an increase of a corner between these components of a field. Here analogy to periodic movement on a circle for a particle having an electrical charge first of all is pertinent. In this case it is possible to speak that between the center of a circle where there is a positively charged nucleus and the particle with a negative charge exists electromagnetic interaction resulting to such movement. For a wave with a wave vector \(k = \omega/c\), where \(c\) is a speed of light, such periodic decision corresponds to the wave equation

\[
\frac{\partial^2 E}{\partial t^2} + c^2 \cdot k \cdot E = 0
\] (55)

If the particle is at fixed energy level, its trajectory can be connected to a trajectory of other pair particles taking place on other energies levels of the same atom. There is an example for a particle fixed on a circle with a radius \((a)\) and driven together with a circle along the allocated direction \((x)\) in space of an atom in a plane \((x, y)\) with a parameter \((T)\) of the corner of turn acts:

\[
x = a \cdot [T - \sin(T)]
\] (56)

\[
y = a \cdot [1 - \cos(T)]
\] (57)

\[
x = \arccos \frac{a - y}{a} \cdot \sqrt{2ay - y^2}
\] (58)

\[
z = x + i \cdot y = a \cdot [T + i \cdot \exp(-i \cdot T)]
\] (59)
It is known, that such trajectory is a projection of movement on a spiral. Radius of curvature monotonously changes in conformity with a sine function:

$$\rho = \left| \frac{1 + \left( \frac{dy}{dx} \right)^2}{\frac{d}{dx} \left( \frac{dy}{dx} \right)} \right| = 4a \cdot \sin \frac{T}{2}$$  \hspace{1cm} (60)

It is easy to notice connection between interpretation of a trajectory for the simple and double frequency of a wave. It is possible, that Radius of curvature $\rho$ of this trajectory for pair fields is variable size and can corresponds to amplitude ($E$) of EM wave, the radius of the circle ($a$) can corresponds to ($E_0$), the corner $T$ can corresponds to $\omega t$. For pair particles it is possible to connect these characteristics with the Rabi frequency.

In each point such curve radius of curvature is perpendicular trajectories and all together such radiuses form other curve, of what it is possible to be convinced if to replace $T = \tau - \pi$.

This will be the same trajectory, but with other coordinates:

$$X + a \cdot \pi = a \cdot [\tau - \sin(\tau)]$$  \hspace{1cm} (61)

$$Y + 2a = a \cdot [1 - \cos(\tau)]$$  \hspace{1cm} (62)

Therefore it is possible to assume, that there is one more field or particle carrying out the same movement with the same frequency and time, but taking place on other circle with same radius. The trajectories of these pair processes will be moved with a phase difference on number ($\pi$) and together they will correspond to one function with variable on a mark by amplitude. Such movement for a particle can be simulated as movement at a fixed energy level with friction ($\gamma$), which is present at the equations of classical and quantum oscillators. Continuing this logic it is possible to enter other parallel trajectories for charges of particles and it is possible to investigate new EM processes.

In connection with the proposed model is possible to approve, that if the order of following functions in investigated physical process is established to within a constant difference of the phase, thus is established possibility to observe a pair physical processes for waves and particles not only at space of the atom or the space of laboratory, but for different spaces.
where the flat part of space in general probably may be divided on inverse sub spaces with in parallel current direct and return processes.

Probably here there should be balanced restrictions on imagination, because it is possible too to assume, that the physical laws containing mathematical functions from even degrees of the arguments should correspond to pair processes and particles "koquark".
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