A possible way to look at the last and future events for two-level system

Evgueni V. Kovarski

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Abstract

In view of a three-dimensional picture (3D) of probability to find a particle at a plane of the frequency and the time (PTF) becomes that process of absorption and process of radiation for two-level system have different direction on the time. Both processes are in the past or in the future depending on named transition due to reversible model of the two-level atom. The opportunity to know the last history of the resonant event for the absorption process is for quantum interference interaction or for the resonant radiation. On the contrary, to predict the resonant event in the future is possible only by use near resonant atom-field absorption or by use radiation at a fixed time. The problem of life time for a particle is entered through time of spontaneous radiation connected with trajectory of the quantum transition. It is offered to connect a trajectory of a particle during quantum transitions with distribution of probability to find a particle. The conception of the spectral history for events due to probability distribution is introduced for next discussion.

31.70., 32.80.
The probability to find a particle on the upper energy level within two - level system is the function of two variables such as the time \( \tau \) and the frequency \( \omega \). We consider \( P(\tau, \omega) \) as the function of probability in system of axis coordinates \( \tau \) and \( \omega \), where we shall to discuss 3D pictures of probability - time - frequency (PTF). Such images underlie present work. On them the connection between events is well visible.

The function \( P(\tau, \omega) \) of probability is a distribution, which has direct connection with observable structures of spectral lines and that reminds similar distribution of the EM signal theory \([1]\). Between these performances of processes exists the problem of recognition for events which occurs in an atom, but are registered in the laboratory \([2]\). Real model can be well imagine if we shall stop more in some physical parameters. For the near resonant absorption problem is usually difficult to imagine why there is an absorption, if there is no exact resonance. It is necessary well to imagine where are frequencies borders of such interaction. The account of spectral width concerns also to this. This is important only for long pulses or continuous wave (\( cw \)) - lasers. Besides to believe in a nature of spontaneous radiation in system not having interactions with anything, except with a field, is difficult. This concerns to no radiating transitions too.

The Rabi frequency \( \Omega_\nu \) measured in (MHz) is:

\[
\Omega_\nu = \frac{d_{1,2} \cdot E_0}{\hbar} \tag{1}
\]

where \( d_{1,2} \) - is the matrix dipole momentum and \( E \) - is the amplitude of EM wave. There is the frequency \( \Omega \), that make a round oscillations between two levels. Each round consist on well known processes of the absorption and the emission due to \( cw \) - laser excitation with the field

\[
E = E_0 \cdot \cos(\omega \cdot \tau) \tag{2}
\]

Therefore, we can consider only the absorption process or the radiation process with the frequency measured in (\text{rad.}/s): \( \Omega = 2\pi \Omega_\nu / 2 = \pi \Omega_\nu \). We shall notice, that considering Rabi frequency as varied parameter, we should operate intensity \( I \) of the \( cw \)-laser in space of laboratory by use the known relation:

\[
\Omega_\nu = \text{const} \cdot \sqrt{I} \tag{3}
\]

The frequency tuning conditions for the quantum interference are:

\[
E(\tau) = E_0 [\cos(\omega_1 \tau) + \cos(\omega_2 \tau)] \tag{4}
\]

\[
\Delta \omega_2 = \omega_2 - \omega_0 \tag{5}
\]

where we set:

\[
\Delta \omega_1 = \omega_0 - \omega_1 \tag{6}
\]

For the quantum interference perturbation of the upper energy level \( W_2 \) \([\text{Fig. 1}]\), there are two symmetrical frequencies, so we can use the relation for exact solution:
\[ \Delta \omega_2 = \Delta \omega_1 = \Delta \omega \]  \hspace{1cm} (7)

Let’s once again address to the well known process of an atom-field interaction, where for events with a particle exist a well known formula for the probability, containing the Rabi frequency \( \Omega \):

\[
P_1 = \left[ \frac{4\Omega^2}{4\Omega^2 + \Delta \omega^2} \right] \sin^2 \left( \frac{\tau}{2} \sqrt{4\Omega^2 + \Delta \omega^2} \right) \]  \hspace{1cm} (8)

The transition probability for the quantum interference effect is [2]:

\[
P_2 = \left[ \sin \left( \frac{\Omega}{\Delta \omega} \cdot \sin(\Delta \omega \tau) \right) \right]^2  \hspace{1cm} (9)

The experiment condition in the visible range of a spectrum for the Lithium atom was chosen. The correspondence between Rabi frequencies and fine structures at the same energy level are shown in the [Fig. 1]. When the amplitude of the laser wave \( E \) is about 8.7 Volt/cm the intensity of the laser is about \( I = 100 \text{ mW/cm}^2 \) and \( \Omega \approx 1000 \text{ MHz.rad.} \), that corresponds to the Rabi frequency \( \Omega_0 \approx 318 \text{ MHz} \) and the intensity \( 375 \text{ mW/cm}^2 \). Because the given value for the Rabi frequency is about 1 \( \text{GHz.rad} \), we can to compare it for Lithium, where the distance between \( 2P_{1/2} \) and \( 2P_{3/2} \) for two isotopes is above \( (2\pi) 10 \text{GHz} \) and the frequency \( \omega_0 \approx 2,8 \cdot 10^6 \text{GHz.rad.} \). Other real parameter is the frequency \( \omega_0 \) of the laser with which is possible very precisely to operate. For real lasers such as the dye-laser (Coherent, Model 899 -21 ) with temperature stabilized reference cell, the frequency drift is only \( 50 \text{ MHz/hour} \) with 500 \( \text{kHz} \) line width. For the quartz rod resonator structure of the broad band dye - laser, SpectraPhysics, 375D with special procedure [3] for a single mode operation a resulting temperature sensitivity was about \( 90 \text{ MHz/}^0\text{C} \). With respect to the refraction coefficient of air a temperature sensitivity is about \( 410 \text{ MHz/}^0\text{C} \). For semiconductors lasers such as the 6202 model of NewFocus diode laser or for the EOSI diode laser, the line width is about 100 \( \text{KHz} \) and the average power 6 \( \text{mW} \), the stability parameters at the needed wave length are better. Therefore it is real to scan an atomic transition with accuracy about \( \Delta \omega = 20 \text{MHz} \)

Imagining real conditions for the two -level model of Lithium atom at \((2S - 2P)\), look at a 3D picture of probability \( P_1 \) [ Fig. 2 ]. The probability \( P_1 \) for the quantum transition is one function as known \( \text{sinc}^2 \) and, as well known from the theory, it is depend on the time too, as the delta function. When we use this probability at the small range of the time (usually named as the probability of transition) we lose the information about the time picture for the quantum process. Therefore in this work we will use only \( P_1 \). It is visible that the limit for \( P_1 = 1 \) exist, because it is possible to present that there is a spatial inclination of function of distribution. It is a new key, which can change our performance about properties and trajectory of a particle [2]. The nature of a spatial inclination \( P_1 \) far from a resonance can be connected with the movement of a particle along the time axis at different frequencies at each level. A new concept for a history of events within the two-level system from here follows. The inclination can occur for two reasons. Firstly, the particle at one level goes along an axis of time with the greater speed, than on the friend. It can result in electrical distribution of charges in time. Secondly, that the particle goes with identical speed, but its way upward or downwards differs from the standard model. We note that for
lowest energy level the pictures differences by the phase. Therefore a direction of time for return transitions (the radiation) will differ is familiar.

Such transformation can be applied to both the understanding of a trajectory of a particle and the life time \( \gamma \). Let us to receive the possible relation between the spontaneous emission time \( t_s \) and the life time \( t_L \) of the particle within a two-level atom having in view of a question about to define them in the time axis. The time of spontaneous emission \( t_s \) is well known:

\[
t_s = \frac{3\pi \hbar c_0^2}{\omega_0^2 d_{21}^2}
\]

where for an atom of Lithium some important parameters are: \( t_s = 27,1 \, \text{ns} \), \( \omega_0 \simeq (2\pi)4,468 \cdot 10^{14}s^{-1} \), the dipole momentum is \( d_{21} = 2,3452 \, \text{a.u. or } 1,988 \cdot 10^{-29} \, \text{C.m.} \). The spontaneous emission time for the Lithium atom is \( t_s = 27,1 \, \text{ns} \). It causes that the system decays with a damping constant \( \gamma_s = t_s^{-1} \) when the EM field is switched off.

Now we shall to explain new definition of the life time \( t_L \). The probability that the particle with the life time having unknown value \( t_L \) will leave the upper energy level, and its spontaneous radiation will fade with known constant \((\gamma_s^{-1})\) is defined by function

\[
G_1 = \gamma_s \cdot \exp(-\gamma_s \cdot t_L)
\]

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:

\[
G_2 = \gamma_L \cdot \exp(-\gamma_L \cdot t_s)
\]

Both functions \( G_1 \) and \( G_2 \) are shown in the [Fig. 3] The function \( G_2 \) has the maximum, when the first function \( G_1 \) decreased to the value \((t_s \exp)^{-1}\) at \( t_L = t_s = 27,1 \, \text{ns} \). The life time from the first function \( G_1 \) is equal to \( 2t_s \) at \( G_{1M}/e^2 \). We can propose that the extremity of the lifetime is at the same \( G_{1M}/e^2 \). Therefore the equation is:

\[
X = \exp(X - 2)
\]

where \( X = t_s/t_L \). The function \( G_2 \) has two interesting solutions for the lifetime \( t_{L2} = t_s \cdot (20/\pi^*) \), \( t_{L1} = t_s/(\pi^*) \) We will use the relation between the life time \( t_L = \gamma_L^{-1} \) and spontaneous emission time \( t_s = \gamma_s^{-1} \) Accuracy is about \((\pi^* = \pi \pm 0.0045)\):

\[
\gamma_s = (19/\pi^*)\gamma_L = (6,048)\Gamma_L
\]

where for \( \gamma_s = 36,9 \, \text{MHz} \) one can easy obtain \( g_L = 6,1 \, \text{MHz} \), that is the quite value of the FWHM for the \( 2S - 2P \) Lorentz spectral line. Also there are two options for introduced lifetime damping coefficient \( \gamma_L \). The first damping coefficient may be equal \( \Gamma_{L9} = \pi^*/20t_s = 5,796 \, \text{MHz} \). The second is \( \gamma_L = \pi^*/19t_s = 6,101 \, \text{MHz} \), see [Fig. 3]. We note that the solution \( 20/\pi^* \) is close with accuracy 0,083 to the value of \( 2\pi \), that is usually used for the frequency scale in radians. However such coefficients are better, then \( 2\pi \) due to the possible confusion for Lithium \( \gamma_s = 2\pi \cdot \gamma_L \). We think that introduced relations are important for the Lithium atom model, because exact values are needed for the theory and experiments. At definition of complete probability for the life time it is necessary to take into account both probabilities [ Fig. 4 ]:
\[ G = G_1 \cdot G_2 = \frac{1}{t \cdot t_S} \cdot \exp \left[ -\frac{t_L^2 + t_S^2}{t_L \cdot t_S} \right] \]  \(15\)

We note that the lifetime \(t_L\) going from function \(G_2\) is oversized the lifetime \(t_L = 2t_s\) from the first distribution \(G_1\) due to possible contribution of no radiative decay. We assume, that it is connected to features of a trajectory of a particle and in this connection with change of speed (acceleration or braking), there is a problem about structure of atom [2].

Both distributions \(P_1\) for a single frequency tuning probability and \(P_2\) for a probability of a quantum interference can be written without mixture effects due to influence of the power broadening by the laser intensity and, therefore, without value of the Rabi frequency \(\Omega_\nu\) in equations for the probability \(P(\Delta \omega, t)\). The introduced axis transformation for 3D pictures are:

\[ \tau \cdot \Omega = X \]  \(16\)

\[ \Delta \omega = Y \cdot \Omega \]  \(17\)

where both the \(X\) and the \(Y\) are linearly variable numbers. Once again we shall pay attention that we do not know as time actually varies. On the contrary the way of changes for a frequency of the laser is well known in each case, therefore with approximation it is possible to consider this change as a linear. At the frequency domain, one can use another time dependence not only linear was used. For example, the presentation of the \(X\) and \(Y\) values are possible with the projections from the complex dipole, when the both axis have the correspondence to the projections of the plane complex vector, e.g. \((sinX)\) and \((cosY)\), where for the upper energy level at the initial time \((t = 0)\) the probability is zero too. It is easy to observe that there are closely pictures for the quantum interference excitation and for the single frequency excitation. These pictures was named atomic PTF lattices, due to the analogy with standing wave picture. It is interesting, but their use is improbable.

We shall show, that in space of atom it is possible to predict events about the future events only if to use interaction with EM field having one frequency and it is possible to know about last events if to use quantum interference effect. We can see the equation of probability-time-frequency at the 3D picture (PTF)[ Fig. 5]. We can precisely tell, that in the same time the particle can pass from below upwards, but also it can move on one of probable ways to the future places creating the future events. The movement upwards will be continuous because the distribution of probability is based on trigonometrical function. The movement on other directions will be quantum. For a fixed time we can predict a future events. In this case it is important to determine frequency of the laser to know in what time a particle will rise upwards. On the other hand measuring spontaneous radiation at the given moment of time we can count that it is that range of time, which corresponds to those PTF trajectories whence in the past the particle has come.

For two symmetrical frequencies a direction of upwards events is opposite [ Fig. 6 ]. For the quantum interference effect one can observe other Rabi oscillations along the time axis \((X)\) with other periods, so it is possible to speak about the future near resonant events. Here is the connection with the theory of dressed atom. The particle is with probability to equal unit simultaneously from both parties from an exact resonance position at once in several places on frequency [ Fig. 7]. There are some open problems such as the duality,
fractional mass and charge. However, if to accept, the particle comes in these places on different trajectories, therefore such problems is not consider.

We note that the Rabi oscillations have the same period for both functions when the frequency tuning is zero and the time of interaction is not too large. The intensity of the laser can transform axis of PTF.

There is the conception of the spectral history as the possible way to look at the last and future events for two-level system in view of a three-dimensional picture (3D) of probability to find a particle at a plane of the frequency and the time (PTF). It becomes that process of absorption and process of radiation for two-level system have different direction on the time. Both processes are in the past or in the future depending on named transition due to reversible model of the two-level atom. The opportunity to know the last history of the resonant event for the absorption process is for quantum interference interaction or for the resonant radiation. On the contrary, to predict the resonant event in the future is possible only by use near resonant atom-field absorption or by use radiation at a fixed time. The problem of life time for a particle is entered through time of spontaneous radiation connected with trajectory of the quantum transition. It is offered to connect a trajectory of a particle during quantum transitions with distribution of probability to find a particle. The conception of the spectral history for events due to probability distribution is introduced for next discussion.

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II. FIGURE CAPTION

Fig.1. Lithium atom 2S – 2P transition as one example.
Fig.2. New 3D picture of the two-level atom.
Fig.3 The relation between the life time and the spontaneous emission time.
Fig.4 Definition of complete probability for the life time.
Fig.5. 3D picture of Probability - Time - Frequency for near resonant interaction.
Fig.6 3D picture of Probability - Time - Frequency for the quantum interference.
Fig.7 The spectral line for the quantum interference at a fixed time.
\[ \omega_0 = (2\pi) \times 4.468 \times 10^5 \text{ GHz} \]
This figure "Fig2.gif" is available in "gif" format from:

http://arxiv.org/ps/quant-ph/0107079v1
\[ G = G_1 \cdot G_2 \left(10^9 / \text{s}^2\right) \]
This figure "Fig5.gif" is available in "gif" format from:

http://arxiv.org/ps/quant-ph/0107079v1
This figure "Fig6.gif" is available in "gif" format from:

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The function \( P(\tau, \omega) \) of probability is a distribution, which has direct connection with observable structures of spectral lines and that reminds similar distribution of the EM signal theory [1]. Between these performances of processes exists the problem of recognition for events which occurs in an atom, but are registered in the laboratory [2]. Real model can be well imagine if we shall stop more in some physical parameters. For the near resonant absorption problem is usually difficult to imagine why there is an absorption, if there is no exact resonance. It is necessary well to imagine where are frequencies borders of such interaction. The account of spectral width concerns also to this. This is important only for long pulses or continuous wave (cw) - lasers. Besides to believe in a nature of spontaneous radiation in system not having interactions with anything, except with a field, is difficult. This concerns to no radiating transitions too.

The Rabi frequency \( \Omega_\nu \) measured in (MHz) is:

\[
\Omega_\nu = \frac{d_{\nu,2} \cdot E_0}{\hbar}
\]

(1)

where \( d_{\nu,2} \) - is the matrix dipole momentum and \( E \) - is the amplitude of EM wave. There is the frequency \( \Omega \), that make a round oscillations between two levels. Each round consist on well known processes of the absorption and the emission due to cw - laser excitation with the field

\[
E = E_0 \cdot \cos(\omega \cdot \tau)
\]

(2)

Therefore, we can consider only the absorption process or the radiation process with the frequency measured in \((rad./s)\): \( \Omega = 2\pi \Omega_\nu / 2 = \pi \Omega_\nu \). We shall notice, that considering Rabi frequency as varied parameter, we should operate intensity \( I \) of the cw-laser in space of laboratory by use the known relation:

\[
\Omega_\nu = \text{const} \cdot \sqrt{I}
\]

(3)

The frequency tuning conditions for the quantum interference are:

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

(4)

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

(5)

where we set:

\[
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For the quantum interference perturbation of the upper energy level \( W_2 \) [Fig. 1], there are two symmetrical frequencies, so we can use the relation for exact solution:
\[ \Delta \omega_2 = \Delta \omega_1 = \Delta \omega \]  \hspace{1cm} (7)

Let’s once again address to the well known process of an atom-field interaction, where for events with a particle exist a well known formula for the probability, containing the Rabi frequency \( \Omega \):

\[ P_1 = \left[ \frac{4\Omega^2}{4\Omega^2 + \Delta \omega^2} \right] \sin^2 \left( \frac{\tau}{2} \sqrt{4\Omega^2 + \Delta \omega^2} \right) \]  \hspace{1cm} (8)

The transition probability for the quantum interference effect is \( [2] \):

\[ P_2 = \left[ \sin \left( \frac{\Omega}{\Delta \omega} \cdot \sin(\Delta \omega \tau) \right) \right]^2 \]  \hspace{1cm} (9)

The experiment condition in the visible range of a spectrum for the Lithium atom was chosen. The correspondence between Rabi frequencies and fine structures at the same energy level are shown in the [Fig. 1]. When the amplitude of the laser wave \( E \) is about 8.7 Volt/cm the intensity of the laser is about \( I = 100 \, mW/cm^2 \) and \( \Omega \approx 1000 \, MHz \text{ rad} \), that corresponds to the Rabi frequency \( \Omega_c \approx 318 \, MHz \) and the intensity 375 \( mW/cm^2 \). Because the given value for the Rabi frequency is about 1 \( GHz \text{ rad} \), we can to compare it for Lithium, where the distance between \( 2P_{1/2} \) and \( 2P_{3/2} \) for two isotopes is above (2\( \pi \)) 10\( GHz \) and the frequency \( \omega_0 \approx 2,8 \cdot 10^6 \text{GHz rad} \). Other real parameter is the frequency \( \omega_0 \) of the laser with which is possible to operate. For real lasers such as the dye-laser (Coherent, Model 899 -21 ) with temperature stabilized reference cell, the frequency drift is only 50 \( MHz/hour \) with 500 kHz line width. For the quartz rod resonator structure of the broad band dye - laser, Spectra Physics, 375D with special procedure \( [3] \) for a single mode operation a resulting temperature sensitivity was about 90 \( MHz/^\circ C \). With respect to the refraction coefficient of air a temperature sensitivity is about 410 \( MHz/^\circ C \). For semiconductors lasers such as the 6202 model of NewFocus diode laser or for the EOSI diode laser, the line width is about 100 \( KHz \) and the average power 6 \( mW \), the stability parameters at the needed wave length are better. Therefore it is real to scan an atomic transition with accuracy about \( \Delta \omega = 20 \, MHz \)

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where for an atom of Lithium some important parameters are: \( t_s = 27.1 \, \text{ns} \), \( \omega_0 \simeq (2\pi)4 \cdot 468 \cdot 10^{14} \, \text{s}^{-1} \), the dipole momentum is \( d_{21} = 2.3452 \, \text{a.u.} \) or \( 1.988 \cdot 10^{-29} \, \text{C.m.} \). The spontaneous emission time for the Lithium atom is \( t_s = 27.1 \, \text{ns} \). It causes that the system decays with a damping constant \( \gamma_s = \frac{G}{t_s^2} \) when the EM field is switched off.

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G_1 = \gamma_s \cdot \exp (-\gamma_s \cdot t_L)
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The probability that the upper level will become empty with a known damping constant \( (\gamma)_{L} \) during the unknown time of spontaneous radiation \( (t_s) \) is:

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G_2 = \gamma_L \cdot \exp (-\gamma_L \cdot t_s)
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Both functions \( G_1 \) and \( G_2 \) are shown in the [Fig. 3] The function \( G_2 \) has the maximum, when the first function \( G_1 \) decreased to the value \( (t_s e)^{-1} \) at \( t_L = t_s = 27.1 \, \text{ns} \). The life time from the first function \( G_1 \) is equal to \( 2t_s \) at \( G_{1M}/e^2 \). We can propose that the extremity of the lifetime is at the same \( G_{1M}/e^2 \). Therefore the equation is:

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X = \exp (X - 2)
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where \( X = t_s/t_L \). The function \( G_2 \) has two interesting solutions for the lifetime \( t_{L2} = t_s \cdot (20/\pi^*) \), \( t_{L1} = t_s/(\pi^*) \) We will use the relation between the life time \( t_L = \gamma_L^{-1} \) and spontaneous emission time \( t_s = \gamma_s^{-1} \) Accuracy is about \( (\pi^* = \pi \pm 0.0045) \):

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\gamma_s = (19/\pi^*) \gamma_L = (6.048)\Gamma_L
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where for \( \gamma_s = 36.9 \, \text{MHz} \) one can easy obtain \( g_L = 6, 1 \, \text{MHz} \), that is the quite value of the FWHM for the \( 2S - 2P \) Lorentz spectral line. Also there are two options for introduced lifetime damping coefficient \( \gamma_L \). The first damping coefficient may be equal \( \Gamma_{L0} = \pi^*/20t_s = 5, 796 \, \text{MHz} \). The second is \( \gamma_L = \pi^*/19t_s = 6, 101 \, \text{MHz} \), see [Fig. 3]. We note that the solution \( 20/\pi^* \) is close with accuracy 0.083 to the value of \( 2\pi \), that is usually used for the frequency scale in radians. However such coefficients are better, then \( 2\pi \) due to the possible confusion for Lithium \( \gamma_s = 2\pi \cdot \gamma_L \). We think that introduced relations are important for the Lithium atom model, because exact values are needed for the theory and experiments. At definition of complete probability for the life time it is necessary to take into account both probabilities [Fig. 4]:

\[
\text{X} = \text{exp}(\text{X} - 2)
\]
\[ G = G_1 \cdot G_2 = \frac{1}{t \cdot t_s} \cdot \exp \left[ -\frac{t_L^2 + t_S^2}{t_L \cdot t_S} \right] \]  

(15)

We note that the lifetime \( t_L \) going from function \( G_2 \) is oversized the lifetime \( t_L = 2t_s \) from the first distribution \( G_1 \) due to possible contribution of no radiative decay. We assume, that it is connected to features of a trajectory of a particle and in this connection with change of speed (acceleration or braking), there is a problem about structure of atom [2].

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\[ \tau \cdot \Omega = X \]  

(16)

\[ \Delta \omega = Y \cdot \Omega \]  

(17)

where both the \( X \) and the \( Y \) are linearly variable numbers. Once again we shall pay attention that we do not know as time actually varies. On the contrary the way of changes for a frequency of the laser is well known in each case, therefore with approximation it is possible to consider this change as a linear. At the frequency domain, one can use another time dependence not only linear was used. For example, the presentation of the \( X \) and \( Y \) values are possible with the projections from the complex dipole, when the both axis have the correspondence to the projections of the plane complex vector, e.g. \( \sin X \) and \( \cos Y \), where for the upper energy level at the initial time \( (t = 0) \) the probability is zero too. It is easy to observe that there are closely pictures for the quantum interference excitation and for the single frequency excitation. These pictures was named atomic PTF lattices, due to the analogy with standing wave picture. It is interesting, but their use is improbable.

We shall show, that in space of atom it is possible to predict events about the future events only if to use interaction with EM field having one frequency and it is possible to know about last events if to use quantum interference effect. We can see the equation of probability-time-frequency at the 3D picture (PTF)[ Fig. 5]. We can precisely tell, that in the same time the particle can pass from below upwards, but also it can move on one of probable ways to the future places creating the future events. The movement upwards will be continuous because the distribution of probability is based on trigonometrical function. The movement on other directions will be quantum. For a fixed time we can predict a future events. In this case it is important to determine frequency of the laser to know in what time a particle will rise upwards. On the other hand measuring spontaneous radiation at the given moment of time we can count that it is that range of time, which corresponds to those PTF trajectories whence in the past the particle has come.

For two symmetrical frequencies a direction of upwards events is opposite [ Fig. 6 ]. For the quantum interference effect one can observe other Rabi oscillations along the time axis \( (X) \) with other periods, so it is possible to speak about the future near resonant events. Here is the connection with the theory of dressed atom. The particle is with probability to equal unit simultaneously from both parties from an exact resonance position at once in several places on frequency [ Fig. 7]. There are some open problems such as the duality,
fractional mass and charge. However, if to accept, the particle comes in these places on different trajectories, therefore such problems is not consider.

We note that the Rabi oscillations have the same period for both functions when the frequency tuning is zero and the time of interaction is not too large. The intensity of the laser can transform axis of PTF.

There is the conception of the spectral history as the possible way to look at the last and future events for two-level system in view of a three-dimensional picture (3D) of probability to find a particle at a plane of the frequency and the time (PTF). It becomes that process of absorption and process of radiation for two-level system have different direction on the time. Both processes are in the past or in the future depending on named transition due to reversible model of the two-level atom. The opportunity to know the last history of the resonant event for the absorption process is for quantum interference interaction or for the resonant radiation. On the contrary, to predict the resonant event in the future is possible only by use near resonant atom-field absorption or by use radiation at a fixed time. The problem of life time for a particle is entered through time of spontaneous radiation connected with trajectory of the quantum transition. It is offered to connect a trajectory of a particle during quantum transitions with distribution of probability to find a particle. The conception of the spectral history for events due to probability distribution is introduced for next discussion.

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II. FIGURE CAPTION

Fig.1. Lithium atom $2S - 2P$ transition as one example.
Fig.2. New 3D picture of the two-level atom.
Fig.3 The relation between the life time and the spontaneous emission time.
Fig.4 Definition of complete probability for the life time.
Fig.5. 3D picture of Probability - Time - Frequency for near resonant interaction.
Fig.6 3D picture of Probability - Time - Frequency for the quantum interference.
Fig.7 The spectral line for the quantum interference at a fixed time.