Photoelectron Spectra Induced by Broad-Band Chaotic Light	Phổ quang điện tử với nguồn kích thích là ánh sáng hỗn loạn dải rộng 5 h 51
We consider a model for laser-induced autoionisation in which the laser light is treated as a chaotic white noise. We solve a set of coupled stochastic integro-differential equations, which are based on the Fano model for autoionisation. For the case of symmetric Fano profile we determine the exact photoelectron spectrum and	Chúng ta xét mô hình tự ion hóa cảm ứng laser trong đó ánh sáng laser được xem là nhiễu trắng hỗn loạn. Chúng ta giải tập hợp các phương trình vi tích phân ngẫu nhiên liên kết, những phương trình này dựa trên mô hình Fano về quá trình tự ion hóa. Đối với trường hợp biên dạng Fano đối xứng, chúng ta xác định phổ quang điện tử chính xác và so sánh với các kết quả của những mô hình trước đây bao gồm các cơ chế phục hồi khác nhau (chéo hóa và không chéo hóa), cũng như phát xạ tự phát. Điều lí thú ở đây là các phương trình trong mô hình của chúng

compare it with the results of previous models including different (diagonal and off-diagonal) relaxation mechanisms, and also spontaneous emission. It is interesting to note that equations of our model are of great similarity to those in the model with radiation damping. I. Introduction Over the period of last few years we observe a growing interest in theoretical treatment of the different ionisation processes of atoms in laser fields. The most interesting example from the point of view of our present work is, so called, laser induced auto-ionisation (LIA). Several papers were already published on that particular subject and they studied the detail characteristics of electron and photon spectra associated with photoexcited autoionisation. Probably the most commonly used atomic model is Fano model [1], based on the original considerations of Fano, concerning Coulomb-mixing of the ionising state (£>0) with continuum. This leads to the nontrivial structure in the continuum i.e. distorts the density of states in continuum. The detailed for-mulation of that model, with special respect to its application in LIA, can be found for example in [2, 3], The advantage of the model Fano-atom + laser light is that it can be solved exactly, even if we include in the standard way, relaxation mechanisms. The effect of purely off-diagonal relaxations, arising from dephasing of the dipole-interactions, as a result of the soft elastic collisions or laser phase drift, has been discussed in [4], while the spontaneous emission to a third	tôi rất giống với các phương trình trong mô hình suy giảm bức xạ. [redacted] trôi giạt pha laser [redacted]

state, beside the initial and autoionising states, was analysed in [5].

Finally there have appeared papers devoted to the photoemission in LIA, due to the spontaneous decay to the ground level [6-8],

[redacted]

On the other hand it is always very interesting if one can, at least to some extent, simulate quantum fluctuations (as is for example spontaneous emission) by classical ones. Probably the best known example is the case of resonance fluorescence (RF). Haake, Haus and Rzazewski [9] studied the model of two level atom in laser field within the same context of comparing different relaxation mechanisms. Three models were proposed and compared: classical atom in classical field, quantized atom in classical field and finally both atom and field were quantized. This remains in very close analogy with our work, because two level atom can be reached from our model as a limit of infinitely narrow structure in continuum (|£?(<«)| - ><5(co)).

[redacted]

The next example, which we would like to mention, comes out from the theory of superfluorescence (SF). It comes out clearly due to the work of Haake et al. [10], that it is possible to describe the buildup of SF pulse, by substitution of the classical statistical fluctuations in the place of quantum noise. This classical fluctuations are then responsible for the initiation of the process.

[redacted]

Encouraged by that and the other examples we have undertaken a similar task, by comparing two different models for LIA, speaking more precisely to confront the predictions of the model for LIA, which include the spontaneous emission (i.e. fields degrees of freedom are quantised, hereafter we will refer to it as a QFM) with that of the model suggested by Rzazewski and Eberly [10], in which the laser field is treated as a classical electromagnetic wave, subjected to the ^-correlated, chaotic fluctuations. One shouldn't also forget that this model is interesting by itself, because it describes electric field amplitude of the multimode laser, operating without any correlation between the modes. We have made a nonperturbative theoretical study of bound to continuum radiative transitions, in which the continuum electron state is reached by near-resonant laser excitation from a lower discrete state. The laser light was decomposed into two parts: the deterministic or coherent part (without fluctuations), the other being randomly fluctuating chaotic component [11], which is the main source of relaxation. We also assumed dipole-strength dis-tribution, which is motivated by Fano's work [4], and was taken to be (we assume that our laser is tuned far from the threshold of the continuum band. Therefore we have decided that we can neglect its existence, and in consequence to neglect a natural cut-off of the function (1.1)). It is obvious that for asymmetric case (with finity asymmetry parameter q) our model would give an infinite saturation rate.	[redacted] [redacted] mật độ [redacted] $$\|\Omega(\omega)\|^2 = \frac{\Omega_0^2 \Gamma}{4\pi(\omega^2+\Gamma^2)} \qquad (q=\infty). \qquad (1.1)$$ [redacted]

In that case the corresponding dipole matrix element reads:

It is due to the infinite spectral width of the stochastic laser light (white noise), nonresonantly interacting with the broad band of continuum states. However for symmetric case (q = oo) our model gives the finite and exact analytic formulas for the spec-trum of the ionised electrons. For the purpose of the comparison we have reached to the adequate formulas (that for photoelectron spectrum) coming from QFM. Rigorous formula (presented hereafter) was derived from the Agarwal paper [12], where two different methods for solving QFM equations are presented. As we have carefully testified, both of them give the same results as far as photoelectron spectrum is concerned.

In the second section we present some details of our model and derive the equation for atomic operators. Then in the third part we present and discuss our results. Instead of presenting rather complicated formula (some details of the calculations leading to that formula can be found in the appendix) we have restricted ourselves to the two interesting physical limits: weak and strong fluctuations.

II. Description of the Model

We start with the Hamiltonian introduced in [2, 4] which describes a model with a bound state lying below the edge of the continuum, the bound and continuum state are coupled by the electromagnetic field

H = ha)QP0 + \dcoha) Craro + }dco0(a»)|0) <col + H.C.
(2.1)

$$\Omega(\omega)=\frac{\Omega_0}{\sqrt{4\pi\Gamma}}\left[\frac{\Gamma}{\omega-i\Gamma}+\frac{\Gamma_1}{(1-iq)(\omega+i\Gamma_1)}\right] \qquad (1.2)$$

[redacted]

[redacted]

[redacted]

$$H=\hbar\omega_0 P_0+\int d\omega\,\hbar\omega\, C_{\omega\omega}+\int d\omega\,\Omega(\omega)|0\rangle\langle\omega|+\text{H.C.} \qquad (2.1)$$

where P0 and Cmm are occupation-number operators for the ground state and for the continuum states repectively, the interaction here is described by the function Q(o)) which tells how strongly different points of the continuous spectrum are coupled to the bound state and was suggested by Fano. By |0> we mean the bound state and |co> stands for the excited state in the dressed continuum [1], Following [6] we define the following operators	[redacted]
Then the Heisenberg equations of motion for the atomic operators P0, Ba, B+, Cmu>, form the complete set and can be easily found by simple comutations of that operators with Hamiltonian (2.1). We have put for simplicity <»o=0.	[redacted] $B_{\omega}=\|0\rangle\langle\omega\|$ $C_{\omega\omega'}=\|\omega\rangle\langle\omega'\|.$ (2.2) [redacted]
In the Heisenberg picture, one obtains the linear equations for the dynamical variables, so the equations for corresponding averaged quantities are easily found using different well-known results from the theory of multiplicative stochastic processes [13]. We assume now that Q(to) has the form:	[redacted] $\Omega(\omega)=f(\omega)(E_0+E(t))\,e^{i\omega_L t}$ (2.4)
where E(t) is characterized by a Gaussian, Markov and stationary process (white noise)	[redacted]
and E0 is a deterministic coherent component of the laser field. The double brackets in (2.5) indicate an Fig. 1. Photoelectron spectrum for the QFM and our model. In our case (chaotic laser light), due to the broad bandwidth of the ionizing light, the	$\langle\langle E(t)\,E^{*}(t')\rangle\rangle=a\,\delta(t-t')$ (2.5) [redacted]

spectrum of outgoing electrons reproduces the original density of the states in the dressed continuum and is always flatter than that of QFM. On this series of graphs we keep the constant value of yjf, A/F and b/F2, while changing a/F (=0.2, 0.5, 0.8)

average over the ensemble of realisations of the process E(t). We consider the following stochastic differential equation

dQ/dt = {A + x(t)B + x*(t)C}Q (2.6)

where Q is a vector function of time and A, B and C are (possibly noncommuting) constant matrices. Then it is a known result in the theory of multiplicative stochastic process that exactly satisfies the nonstochastic equation:

d «G»/dt = [A + a {B, C}/2] «Q» (2.7)

where {B, C} is the anticommutator of B and C. Before averaging however we transform dynamical variables to the rotating frame:

Ba=f*(m)Dcoe~i^

Ccoa> '=/V)/*M£w-

Fig. 2. In the limit of the strong field, photoelectron spectra of both models exhibit characteristic Autler-Townes splitting, but the buildup of the two-peak’s structure is slightly different. We see this buildup for growing value of laser field intensity (6 = 0.025, 0.25, 2, in the units of F2). Again, our model gives flatter spec¬trum. Remaining parameters {A/T, a/F, yJF) are kept constant

[redacted]

[redacted]

$$\mathrm{d}Q/\mathrm{d}t = \{A + x(t)\,B + x^*(t)\,C\}\,Q \qquad (2.6)$$

[redacted]

$$\mathrm{d}\langle\langle Q\rangle\rangle/\mathrm{d}t = [A + a\,\{B, C\}/2]\,\langle\langle Q\rangle\rangle \qquad (2.7)$$

[redacted]

$$B_{\omega} = f^*(\omega)\,D_{\omega}\,\mathrm{e}^{-\mathrm{i}\omega_L t}$$
$$C_{\omega\omega'} = f(\omega')\,f^*(\omega)\,E_{\omega\omega'}.$$

[redacted]

The new quantities Dm, Eauj. together with P0 satisfy the following closed set of equations:
dP0/dt = -ijdco |/(co)|2 l(E0+E(t)) D0-(Et
+ E*(t))Dn
dD+/dt = i(coL- co) - i (E* + E*(t)) P0
+ i$dw'\f(cD')\2(E*+E*(t))Ea,a
dEcoa,-/dt = i (co- co') Ew<0. + i(£0 + E(t)) D0).
-i (E*+E*(t))D£. (2.8)

[redacted]

$$
\begin{aligned}
\mathrm{d}P_0/\mathrm{d}t &= -\mathrm{i}\int \mathrm{d}\omega\,|f(\omega)|^2\,[(E_0+E(t))\,D_\omega-(E_0^* + E^*(t))\,D_\omega^+] \\
\mathrm{d}D_\omega^+/\mathrm{d}t &= \mathrm{i}(\omega_L-\omega)\,D_\omega-\mathrm{i}(E_0^*+E^*(t))\,P_0 + \mathrm{i}\int \mathrm{d}\omega'\,|f(\omega')|^2\,(E_0^*+E^*(t))\,E_{\omega'\omega} \\
\mathrm{d}E_{\omega\omega'}/\mathrm{d}t &= \mathrm{i}(\omega-\omega')\,E_{\omega\omega'}+\mathrm{i}(E_0+E(t))\,D_{\omega'} - \mathrm{i}(E_0^*+E^*(t))\,D_\omega^+ .
\end{aligned}
\tag{2.8}
$$

Next, using (2.7) we obtain the system of equations for stochastic averages of the variables (double brackets have been dropped for convenience):
dPJdt = -aFP0 -i Jdm' |/(g/)|2(£>^-D$)
+ ajj|/(co')|2 |/(®")|2iwda>'d«" (2.9 a)
dDJdt= -ibP0 + [_i{coL-co)-aF/2~\ Da
~ fl/2 J | / (ffl')l2 £*<»' d co'
+ ib$\f(co')\2Em-mda>' (2.9b)
dEaJdt=aP0 + i{Da.-D+) + i((o-(o')Eaa.
-a/2j\f(CO")\2(E^a. + Ea^)dco" (2.9c)
where F= j |/(co)|2, b = \E0\.

[redacted]

$$
\begin{aligned}
\mathrm{d}P_0/\mathrm{d}t &= -aFP_0-\mathrm{i}\int \mathrm{d}\omega'\,|f(\omega')|^2\,(D_{\omega'}-D_{\omega'}^+) \\
&\quad + a\iint |f(\omega')|^2\,|f(\omega'')|^2\,E_{\omega'\omega''}\,\mathrm{d}\omega'\,\mathrm{d}\omega''
\end{aligned}
\tag{2.9 a}
$$

$$
\begin{aligned}
\mathrm{d}D_\omega/\mathrm{d}t &= -\mathrm{i}bP_0+[\mathrm{i}(\omega_L-\omega)-aF/2]\,D_\omega \\
&\quad -a/2\int |f(\omega')|^2\,D_{\omega'}\,\mathrm{d}\omega' \\
&\quad +\mathrm{i}b\int |f(\omega')|^2\,E_{\omega'\omega}\,\mathrm{d}\omega'
\end{aligned}
\tag{2.9 b}
$$

$$
\begin{aligned}
\mathrm{d}E_{\omega\omega'}/\mathrm{d}t &= aP_0+\mathrm{i}(D_{\omega'}-D_\omega^+)+\mathrm{i}(\omega-\omega')\,E_{\omega\omega'} \\
&\quad -a/2\int |f(\omega'')|^2\,(E_{\omega''\omega'}+E_{\omega\omega''})\,\mathrm{d}\omega''
\end{aligned}
\tag{2.9 c}
$$

The equation corresponding to the adjoint operator D + is easily found from (2.8b) by complex conjugation.

[redacted]

At that stage we would like to add a few words of comment. We see that our final set of equations has reproduced all of the terms, which appeared in QFM, but also contain new terms. Occurrence of these terms should not surprise us; they are the footprints of the fact that the origin of our relaxations are the classical fluctuations. Following that, we see that for example term aF/l” in equation

[redacted]

(2.9b) appears also in QFM when our laser has randomly fluctuating phase. The other two additional terms (“ —aFP” in equation (2.9 a) and “+aFP” in (2.9 c)) exemplified the straightforward ionisation from the ground level to the continuum. This leads to the line broadening of the Photoelectron Spectrum PS (it is clearly seen in the limit of the large fluctuations) and it is a new feature in comparison to the QFM.	[redacted]
Finally we can recognize that, in absence of the coherent part of the laser light, an important simplification can be reached. Namely Dm and D + drop out. As they vanished at the moment, they remain equal to zero throughout the evolution (the corre-sponding equation for the time derivative of Da is proportional only to Dm and D*, and not to the P0 and Cw). It means that no coherence between the bound state and the continuum can be developed in this case. This is not surprising, considering the physical features of the white noise model. The consequence of that fact will be given in the following paragraph.	[redacted]
III. Photoelectron Spectrum in the Case of One-Lorentzian Continuum	[redacted]
As has been mentioned before, we discuss the one lorentzian case of Fano profile (see (1.1)). It has been recognized in [2] that this case is physically meaningful, because the photoionisation process here is close to the more complex two photon process of Stimulated Raman Scattering. The connection with the double optical resonance phenomena in general was made by Lambropoulos	[redacted] $$W(\omega)=\lim_{t\to\infty} C_{\omega\omega}(t) \qquad (3.1)$$

and Zoller [3], Our model allows the spectrum, i.e.

= (3.1)

t-> cc

to be computed directly and completely analytically. The method is given in the Appendix.

For comparison of our results with the predictions of QFM, we have calculated PS of the latter on the basis of the paper of Haus et al. [6, 7]. It turns out that our results are completely the same as the Agarwal formula [12] and it looks as follows:

W(a)

(c2 - A2)(A2 y2 + c2)/4nc

r o2 i2

\m2 + A(o--~-yt{yl + ys)^ + [_cco + A(y1 + ys)]2

v, ,, (3'2)

where A = — a>L

c=yt+7i+ys y=y,-ys-yi

2 A = — (a>L+Qo)-|-y2

+]/©£ + 2 ©L(y2 + £2g) + (y 2 — QI)2.

As the final formula for our model is rather complicated, now let us consider two limits interesting from the physical point of view:

a) Weak Fluctuations

By that we mean bpaT, i.e. the coherent part of the light dominates over the fluctuations. On the first graph one can see the evolution of PS towards the Autler-Townes splitting for the growing values of Z>(~fl2). We see that either our model or QFM approaches the same limit. It is not surprising because as the fluctuations loose their importance the leading pattern for both models remains the strong population oscillations between ground state and distorted continuum (as appropriate for b>F2).

[redacted]

[redacted]

$$W(\omega) = \frac{(c^2 - A^2)(\Delta^2 \gamma^2 + c^2)/4\pi c}{\left[\omega^2 + \Delta\omega - \frac{\Omega_0^2}{4} - \gamma_t(\gamma_1 + \gamma_s)\right]^2 + [c\,\omega + \Delta(\gamma_1 + \gamma_s)]^2} \quad (3.2)$$

where $\Delta = -\omega_L$

$$c = \gamma_t + \gamma_1 + \gamma_s$$

$$\gamma = \gamma_t - \gamma_s - \gamma_1$$

$$2A = -(\omega_L + \Omega_0^2) + \gamma^2 + \sqrt{\omega_L^4 + 2\omega_L(\gamma^2 + \Omega_0^2) + (\gamma^2 - \Omega_0^2)^2}.$$

[redacted]

[redacted]

After some very simple algebra we could obtain that for a = 0 our PS becomes exactly that of Rzazewski and Eberly [4] for the model without relaxations:

£b/4

nW ® T2^ —co)2 + [fo/4 + (o(coi-a))]2

b) Strong Fluctuations

In this case the coherent part of the laser light is negligible in comparison with the chaotic component. Due to the broad band of the ionising light the spectrum of outgoing electrons reproduces the original density of the states in the continuum, elastic peak becomes supressed. We observe here, that what we have already called direct ionisation (term in the RHS of the equation (2.9 a), proportional to P0) and that differ our model from QFM (it is the feature of the chaotic fluctuations and not of the spontaneous emission) plays now the main role. As we have already mentioned above due to the disappearance of the coherences for PS for the pure noisy light (without coherent part, b= 0) can be easily derived:

71W1 (co) = (a + r)/[(fl + n2 + co2].

Further if we restrict the range of F values (i.e. both b/F and F small in comparison with a) we can even calculate the correction linear in b:

71 W(co) =71 W^to)

b{a[(a + r)2 -co2] + 2m(a + r)(mL—m)} 47t{[a2+(coL— co)2[[(a + r)2 + co2]2} '

We would like to express our gratitude

[redacted]

$$\pi W(\omega)=\frac{\Gamma b/4}{\Gamma^2(\omega_L-\omega)^2+[b/4+\omega(\omega_L-\omega)]^2}.$$

[redacted]

[redacted]

$$\pi W_1(\omega)=(a+\Gamma)/[(a+\Gamma)^2+\omega^2].$$

[redacted]

$$\pi W(\omega)=\pi W_1(\omega)-\frac{b\{a[(a+\Gamma)^2-\omega^2]+2\omega(a+\Gamma)(\omega_L-\omega)\}}{4\pi\{[a^2+(\omega_L-\omega)^2[[(a+\Gamma)^2+\omega^2]^2\}}.$$

to J.H. Eberly and K. Rzaz- ewski for suggesting the problem, and to (K.R.) for his continuous assistance during the preparation of that paper. We also thank M. Lewenstein for very useful discussions.

Appendix

Solution of integro-differential equations of motion for the atomic operators (Eq. (2.9)).

We will denote with a tilde the Laplace transform of the exact quantum mechanical and stochastic average of arbitrary variable:

Then taking the Laplace transform of Eqs. (2.9) and denoting |/(co)|2 =S(co), we obtain

Then one finds that: A~(z)

D =

z + a/%—i(mL — m) i b

-jd co'S(co') (A.4a)

[redacted]

[redacted]

[redacted]

[redacted]

$$\hat{Q}(z)=\int \mathrm{d}t \exp(-z t)\langle\langle Q(t)\rangle\rangle. \qquad (A.1)$$

[redacted]

$$z\tilde{P}_0-1=-aF\tilde{P}_0-\mathrm{i}\int \mathrm{d}\omega'(\tilde{D}_{\omega'}-\tilde{D}^{+}_{\omega'})S(\omega') + \iint S(\omega')S(\omega'')\tilde{E}_{\omega'\omega''}\,\mathrm{d}\omega'\,\mathrm{d}\omega'' \qquad (A.2a)$$

$$z\tilde{D}_\omega=-\mathrm{i}b\tilde{P}_0+\left[\mathrm{i}(\omega_L-\omega)-\frac{aF}{2}\right]\tilde{D}_\omega -\frac{a}{2}\int \mathrm{d}\omega'\,\tilde{D}_{\omega'}S(\omega')+\mathrm{i}b\int \mathrm{d}\omega'\,S(\omega')\tilde{E}_{\omega'\omega} \qquad (A.2b)$$

$$z\tilde{E}_{\omega\omega'}=aP_0+\mathrm{i}(\tilde{D}_{\omega'}-\tilde{D}^{+}_{\omega})+\mathrm{i}(\omega-\omega')\tilde{E}_{\omega\omega'} -\frac{a}{2}\int \mathrm{d}\omega''\,S(\omega'')(E_{\omega''\omega'}+E_{\omega\omega''}) \qquad (A.2c)$$

[redacted]

$$P_0|_{t=0}=1$$

$$D_\omega|_{t=0}=E_{\omega\omega'}|_{t=0}=0.$$

[redacted]

$$A^{-}(z)=-\mathrm{i}bP_0-\frac{a}{2}\int S(\omega')D_{\omega'}\,\mathrm{d}\omega'. \qquad (A.3)$$

[redacted]

<table>
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z + a/8—i(coL —to)'

The equation for D+ is found in the similar way

A + (z)

Dl =

z + a/S + i(mL — m)

+ ^ z + a/% + \(mL — m)

where A + (z) is also simply a hermitian conjugate of (A.3). We assume the separation property of Ema), [6]:

[z —i(co — co')] Eaa>, = £Jz) + rim,(z)

This decomposition is of the greatest importance in the whole procedure of solving our equations. For the case of Symmetric Fano Profile the new functions and rjm satisfy the following equations (we introduce the new a'=a/8 and drop the prime)

i^4 + (z)

H+(z, m)i;a = 4aP0 —

z + a + i(coL —co)
</td>
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$$D_\omega^- = \frac{A^-(z)}{z+a/8-\mathrm{i}(\omega_L-\omega)} + \frac{\mathrm{i}b}{z+a/8-\mathrm{i}(\omega_L-\omega)} \int \mathrm{d}\omega'\, S(\omega')\, E_{\omega'\omega} \qquad \text{(A.4a)}$$

[redacted]

$$D_\omega^+ = \frac{A^+(z)}{z+a/8+\mathrm{i}(\omega_L-\omega)} + \frac{\mathrm{i}b}{z+a/8+\mathrm{i}(\omega_L-\omega)} \int \mathrm{d}\omega'\, S(\omega')\, E_{\omega\omega'} \qquad \text{(A.4b)}$$

[redacted]

$$[z-\mathrm{i}(\omega-\omega')]\, E_{\omega\omega'} = \xi_\omega(z) + \eta_{\omega'}(z) \qquad \text{(A.5)}$$

[redacted]

$$H^+(z,\omega)\,\xi_\omega = 4aP_0 - \frac{\mathrm{i}A^+(z)}{z+a+\mathrm{i}(\omega_L-\omega)} - \left[4a + \frac{b}{z+a+\mathrm{i}(\omega_L-\omega)}\right] \int \frac{S(\omega')\,\eta_{\omega'}}{z+\mathrm{i}(\omega'-\omega)}\,\mathrm{d}\omega' \qquad \text{(A.6)}$$

[redacted]

$$H^-(z,\omega)\,\eta_\omega = 4aP_0 + \frac{\mathrm{i}A^-(z)}{z+a-\mathrm{i}(\omega_L-\omega)} - \left[4a + \frac{b}{z+a-\mathrm{i}(\omega_L-\omega)}\right] \int \frac{S(\omega')\,\xi_{\omega'}}{z-\mathrm{i}(\omega'-\omega)}\,\mathrm{d}\omega' \qquad \text{(A.7)}$$

[redacted]

$$H^\pm(z,\omega) = 1 + \frac{a}{z+\Gamma\mp\mathrm{i}\omega} + \frac{b}{4(z+\Gamma\mp\mathrm{i}\omega)[z+a\pm\mathrm{i}\Delta(\omega)]} \qquad \text{(A.8)}$$

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rja satisfies a similar equation with a complex amplitude D~. Inserting expressions for c,w, r}w in Eqs. (A.6) and (A.7) we obtain after simple algebra
\A (z)
D+ = -{4aPCl +
z + a + T — icoL + D~lH-(z, -ir)-l]j
H~(z, -ir) (A. 10)
and D~ satisfies an analogous equation with A~^A+, H~{z,-ir)^H+{z,ir). Using (A.3)-(A.9) and definitions of A+ we have the following equation
h±(z)A±(z)
= ±ibP0 +

where h±(z) = 1+-
(A. 12)
z + a + T + icoL

In the similar way Eq. (A.2a) gives us P0={D++D- +4)/z.
(A. 13)

Equations (A. 10), (A. 11) and (A. 13) are linear algebraic equations whose solutions are easily found. The spectral distribution of excited electrons is determined from CaJt). In the steady state (corresponding to complete ionisation) at f = co, only the pole at z=0 in the Laplace domain contributes. From the definition of Eae>, and its separation property one

[redacted]

$$\xi_\omega = \frac{4aP_0}{H^+} - \frac{\mathrm{i}A^+(z)}{[z+a+\mathrm{i}(\omega_L-\omega)]H^+} + \frac{D^+\left[4a+\dfrac{b}{z+a+\mathrm{i}(\omega_L-\omega)}\right]}{4(z+\Gamma-\mathrm{i}\omega)H^+} \qquad (A.9)$$

[redacted]

$$D^+ = -\left\{4aP_0 + \frac{\mathrm{i}A^-(z)}{z+a+\Gamma-\mathrm{i}\omega_L} + D^-[H^-(z,-\mathrm{i}\Gamma)-1]\right\} \Big/ H^-(z,-\mathrm{i}\Gamma) \qquad (A.10)$$

[redacted]

$$h^\pm(z)A^\pm(z) = \pm\mathrm{i}bP_0 \mp \frac{\mathrm{i}ab/4}{(z+2\Gamma)(z+a+\Gamma\pm\mathrm{i}\omega_L)}(D^+ + D^-) \qquad (A.11)$$

[redacted]

$$h^\pm(z) = 1 + \frac{a}{z+a+\Gamma\pm\mathrm{i}\omega_L}. \qquad (A.12)$$

[redacted]

$$P_0 = (D^+ + D^- + 4)/z. \qquad (A.13)$$

[redacted]

$$\tilde{C}_{\omega\omega}(z) = |f(\omega)|^2 \frac{\xi_\omega(z)+\eta_\omega(z)}{z} \qquad (A.14)$$

obtains Cao Long Van Institute for Theoretical Physics Polish Academy of Sciences al. Lotnikow 32/46 PL-02-668 Warsaw Poland caJz)=i/MI Thus the spectrum W(m) is given by ,,,, , -TReUO) w<a)-2Mcs+n The explicit form of W is explored in Sect. III.	[redacted] $$W(\omega)=\frac{\Gamma \operatorname{Re} \xi_\omega(0)}{2\pi(\omega^2+\Gamma^2)}.$$ [redacted]