Comment on "Delayed luminescence of biological systems in terms of coherent states" [Phys. Lett. A 293 (2002) 93]

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Abstract

Popp and Yan [F. A. Popp, Y. Yan, Phys. Lett. A 293 (2002) 93] proposed a model for delayed luminescence based on a single time-dependent coherent state. We show that the general solution of their model corresponds to a luminescence that is a linear function of time. Therefore, their model is not compatible with any measured delayed luminescence. Moreover, the functions that they use to describe the oscillatory behaviour of delayed luminescence are not solutions of the coupling equations to be solved.

Key words: Delayed luminescence; Hyperbolic oscillations; Coherent states; Biophotonics
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1. Introduction

Popp and Yan proposed a model for delayed luminescence based on a single time-dependent coherent state [1]. The standard explanation of delayed luminescence from plants is made in terms of Photosystem II reaction centers [2,3], but the Popp and Yan approach is often considered to be a possible alternative (see Refs.[4–7] for recent references).

Moreover, the assumed validity of the Popp and Yan model is used as a confirmation of a very speculative theory claiming that light is used by cells for organizational tasks ("[. . .] the capacity of living systems to trap light and to use it for organizational tasks" [8]).

These applications make it useful to check the validity of the model of Popp and Yan. In this comment, we point out that the hyperbolic decay of delayed luminescence cannot be described by the Popp and Yan model, and that the function they obtain to describe the oscillations of delayed luminescence is not consistent with their coupling equations.

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2. Hyperbolic relaxation

The primed equations refer to ref. [1]. The time-dependent Hamiltonian given by eq. (2') has the solution $|\alpha\rangle$, which is a coherent state, i.e. an eigenstate of the annihilation operator $a(t)$ (in the Heisenberg picture) such as $a(t)|\alpha\rangle = \alpha(t)|\alpha\rangle$, where $\alpha(t)$ is a complex function of t. The general form of $\alpha(t)$ is (correcting two misprints in eq. (5')),

$$\alpha(t) = \mathrm{e}^{-i\psi(t)}\Big(\alpha(0) - i\int_0^t f(t')\mathrm{e}^{i\psi(t')}dt'\Big). \qquad (1)$$

The number of photons as a function of time is given by $n(t) = \langle\alpha|a^+(t)a(t)|\alpha\rangle = |\alpha(t)|^2$. Thus,

$$n(t) = \left| \alpha(0) - i \int_0^t f(t') \mathrm{e}^{i\psi(t')} dt' \right|^2. \qquad (2)$$

By assuming "homeostasis" and the fact that "α should not be influenced by external classical energy sources" (we do not comment here on the validity of these assumptions), Popp and Yan obtain eq. (9') for f, with general solution $f(t) = f(0)\mathrm{e}^{-i\psi(t)}$. Note that, at this stage, Popp and Yan consider a special $\omega(t)$ while we use a general one. By introducing this value of $f(t)$ into eq. (2), we obtain

$$n(t) = |\alpha(0) - i f(0) t|^2. \qquad (3)$$

Therefore, $n(t)$ is a quadratic function of t, independent of $\omega(t)$.

The relation between the intensity of light $I(t)$ and $n(t)$ is not given explicitly in Ref. [1], but the caption of Fig. 3 shows that the authors use the relation $I(t) \propto \dot{n}(t)$. It follows from eq. (3) that $I(t)$ is a linear function of time. This does not agree with any measurement of delayed luminescence.

Therefore, the experimental hyperbolic relaxation given in eq. (17') is not a consequence of the coherent-state model of the paper.

3. Oscillations

Popp and Yan claim that the oscillatory behavior of delayed luminescence can be explained by a coupling of two coherent states $|\alpha_1\rangle$ and $|\alpha_2\rangle$ described by differential equation (18'). We shall see that this interpretation meets a rather serious inconsistency. In their calculation, they use eq. (18') to derive eq. (21') and solve eq. (21') with α_1 and α_2 defined by eq. (22'). However, these α_1 and α_2 are not solutions of the starting eq. (18'). In other words, their "solutions" do not solve the coupling equation they assume. The point is that a solution of eq. (21') is generally not a solution of eq. (18'). Indeed, take any differentiable real function $y_1(t)$ and define $y_2 = y + y_1$, with

$$y(t) = \kappa \ln(1 + \lambda_1 t) - \kappa \ln(1 + \lambda_2 t) + \phi.$$

Then, $\alpha_1(t) = |a_1|\mathrm{e}^{-iy_1(t)}$ and $\alpha_2(t) = |a_2|\mathrm{e}^{-iy_2(t)}$ define a solution of eq. (21') which is not a solution of eq. (18').

4. Conclusion

The main purpose of this comment was to show that the coherent state model proposed by Popp and Yan does not agree with delayed luminescence experiments: the math is simply wrong.

Other points of the paper could also have been discussed. For instance, the density corresponding to a linear combination of coherent states is not given by $n(t) = |\alpha_1(t) + \alpha_2(t)|^2$ (see ref. [9]), the question why the two coherent states should have the same weight, and so on. But we think that our argument is strong enough already.

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