On coherence theory of biophoton emission

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ABSTRACT

This paper presents a review on some basic aspects of coherent theory of biophonon emission.

Keywords: coherence, biophonon emission.

1. INTRODUCTION

Biophoton emission can be considered to originate from a coherent nonlinear interaction between many biological molecules. Such an interaction can be described by means of the various physical models [1], which are associated with thermodynamics, nonequilibrium statistical physics, chaos theory, coherent states of quantum optics, cooperative-radiation theory, and cavity quantum electrodynamics. These models combine into a system of theoretical descriptions in terms of "coherence" mechanism, which is regarded as "coherence theory of biophoton emission" by Popp [2,3]. In the present paper, some aspects of this theory will be mentioned basically.

2. BASIS OF COHERENCE THEORY

Coherence theory of biophoton emission is based on an essential understanding of biological systems as follows:

(1) Openness

Biological systems are essentially open systems, which are "pumped" by external energy sources and retain considerably large deviations from thermal equilibrium. Such a nonequilibrium state of biological systems leads probably to a long-range coherence in them. The biophotons may thus be traced back to the coherence, carrying information within and between cellular systems [4].

(2) Nonlinearity

Vital phenomena are highly nonlinear. The macroscopic properties of a biological system cannot be represented by a simple summation of the microscopic properties of its respective subsystems. In fact, all the subsystems are integrated through a correlation that results in a complex system with a certain macroscopic order. The order parameter of the complex system displays a nonlinear dynamics as well as nonlinear depends on the physiological parameters [5].

(3) Cooperativity

Life actions are collective effects of many biological subjects, and there is a cooperation between the individual subjects [6]. Such a cooperation can be either constructive or destructive, which is determined, with respect to Dicke's cooperative-radiation theory, by the symmetry of the state in which the many subjects interact with each other. There is good experience to believe that destructive interaction plays a more essential role in life processes [7-9].

3. THE f_n =CONSTANT_RULE

Let us mention one of the most essential results of coherence theory of biophoton emission, which is displayed by the f_n =constant-rule. It is well know that a non-living matter in the thermal equilibrium displays a well-known Boltzmann distribution of energy level according to

$$f_i = \exp\left(-\frac{E_i}{KT}\right) \tag{1}$$

where E_i is the energy of th-i level, KT is the mean thermal energy at temperature T. In contrast, the energy-level distribution of living matter is found to be subject to the f_n =constant-rule. This rule is established on the basis of the laws of thermodynamics in such a way that the temperature T of a heat bath is replaced by an "excitation temperature" $\Theta(n)$ in dependence on frequency n , resulting in a new Arrhenius factor:

$$f_n = \exp\left(-\frac{E_n}{K\Theta(n)}\right), \tag{2}$$

where $\Theta(n)$ can be calculated from the spectral biophoton intensity i_n (photons per units of area, time, frequency and solid angle):

$$\Theta(n) = \frac{hn}{K \ln\left(\frac{2n^2}{i_n c^2}\right)}, \tag{3}$$

with c as the velocity of light.

In contrast to thermal radiation with $i_n = \frac{2n^2}{c^2}\exp\left(-\frac{hn}{KT}\right)$, we get a remarkable result for biological tissue:

$$\Theta(n) \propto n \tag{4}$$

and in the optical range:

$$\Theta(n) >> T \tag{5}$$

The insertion of (4) into (2) results in the rule:

$$f_n = \text{constant} \ . \tag{6}$$

Now, one can understand the audio-visual implication of f_n =constant-rule in comparison with the Boltzmann distribution. For simplicity, we consider the two-level case and denote the numbers of radiators in the excited states for living matter and non-living matter in thermal equilibrium as N_l and N_n ,respectively, arriving at the relation

$$\frac{N_l}{N - N_n} = f_n\,(const.) >> \exp\left(-\frac{hn}{KT}\right) = \frac{N_n}{N - N_n} \tag{7}$$

where N is the total number of radiators of each system and T represents a physiological temperature, this relation yields

$$N_l >> N_n \tag{8}$$

which means that the excited states of living matter are occupied with much more radiators compared to these of the non-living matter in thermal equilibrium.

The f_n =constant-rule can also be derived from the maximum-entropy formalism for an open system, starting with the general expression of the entropy of an ensemble of systems:

$$S = -K\sum_i f_i \ln f_i \tag{9}$$

where K is Boltzmann constant and f_i is the probability of finding the system in state i. For an open system, there are no constraints except the normalized condition:

$$\sum_i f_i = 1 \tag{10}$$

The entropy may be visualized physically as a measure of the lack of information of the system. If we know the system in a definite state j, then $f_i = d_{ij}$, and we see by (9) that the entropy is zero. In this case we have complete information about the system. On the other hand, if we know nothing about the system, it is equally likely to find the system in any of its possible states. Let us maximize the entropy (9) under the constraint (10) in order to obtain a distribution representing “complete ignorance” . This problem can be solved by using the usual method of Lagrange parameters. After multiplying the left-hand-side of (10) by a parameter ?, adding it to the Right-hand-side of (9), the variation of the total sum with respect to ?? has to vanish, resulting in

$$\sum_i (1+\ln f_i + l)df_i = 0 \tag{11}$$

Each df_i is now independent, and Eq. (11) will be satisfied if and only if each term is zero:

$$\ln f_i = -(1+l) \tag{12}$$

From this readily deduce Eq. (6); that is, the probability of finding the system in any of its states is equally likely.

The f_n =constant-rule provides the basis for understanding a variety of extraordinary properties of living tissues and living actions, namely

(1) With the ingenious way of nature in optimizing the living state, living system keep an absolute maximum of entropy but at the same time they are able to minimize the entropy value by means of reducing the number *w* of degrees of freedom. This case may take place, for instance, in the DAN [2], where $W \rightarrow 1$ and entropy $S = \ln W \rightarrow 0$.

(2) The f_n =constant-rule provides the best way of explanation of the transparency effect, that is, living matter may exhibit a high degree of transparency for passing of biophotons, for example, the biophotons from cucumber seedlings are found to pass through soy cells almost without loss of there energy. This is essentially a “bleaching effect” of living matter for coherent photons, caused by a fact that the excited states of living matter are occupied with quite a high probability.

(3) This rule is associated with such a fact that biological systems display the highest possible signal/noise-ratio. In fact, the f_n =constant-rule can be directly obtained by optimizing the signal/noise-ratio defined by

$$SNR = \frac{\dot{n}}{4\Delta n}\left[\exp\left(\frac{hn}{K\Theta(n)}\right) - 1\right] \tag{13}$$

The highest possible signal/noise-ratio of biological systems may also be the reason of the well-known high sensitivity of biological systems.

(4) The f_n =constant-rule governs a nonequilibrium phase transition between an ordered, lowly dissipative state and a chaotic, highly flexible state. The biological system remains around the critical point of the phase transition, where a coherent radiation of a multi-mode biophoton field induced by collective bio-radiators can get quasi-stabilized.

(5) One of the consequences of the rather high f-values is that the biochemical reaction rate can be many orders of magnitude higher in a living tissue than in a thermal equilibrium system at physiological temperature. This is due to liberation of energy stored in the excited states of living matter during the biochemical reaction. It is useful to elucidate the connection between the f_n =constant-rule and the spectral entropy s of a light beam travelling through the living tissue. Following Planck

$$S \propto \frac{1}{t}\left[(1+it)\ln(1+it) - it\ln(it)\right] \tag{14}$$

where *i* is the photon intensity, t the coherence time, and

$$f_n = it \tag{15}$$

one can obtain from (14), (15) and the f_n =constant-rule that

$$it = \text{constant}\ , \tag{16}$$

$$St = \text{constant}\ , \tag{17}$$

$$i/S = \text{constant}\ . \tag{18}$$

These results indicate that a decrease of biophoton intensity *i* may be due to a prolongation of the coherence time t, which corresponds to a decrease of the entropy *S*, implying an increase of order in the system under consideration.

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News

Optics 21 Promotes Light as a Tool

Optics is an enabling technology, two German scientific societies told their government's research ministry, BMBE. They believe that light now offers technical solutions to order but that industry does not know what to ask for.

The societies want a national response to the US Harnessing Light program to place optics at the heart of technology in the next century. A group in the UK is planning a similar initiative.

"Light has become a versatile tool that can be used universally,"
said the German Scientific Laser Society and the country's optical association in a memorandum to the BMBE called Optics 21.

The memo also argues that the laser puts "science in the position to give the 'light' medium new properties unknown in nature. The possibilities in the medium have not yet been exhausted."

It states that optics now makes unique applications possible in fields such as production engineering, metrology, optoelectronics and biology. "Optics technologies have reached a position to take up the far-reaching challenge of shaping and using the 'light' medium in almost any way."

It ends by saying: "Optics must be recognized as a new key technology with its transdisciplinary potential yet to be fully employed."

One signatory of Optics 21 told OLE that Harnessing Light was one of similar studies in the US, 35 of which have been carried out by the National Science Foundation in the past 18 months.

The next step in Germany is to coordinate industry and research into different ways of thinking. Industry must see that research relates to more than single products; researchers must see that long-term research can be directed at given ends in novel fields.

He was optimistic about changing thinking. In 1998 German industry began bringing research back in house, and unemployment among young scientists fell rapidly for the first time in five years. (*original news by John Bell*)

(*Dr. Hexin Wang, Carl Zeiss Lithos GmbH*)