Front. Optoelectron. 2014, 7(1): 28–36
DOI 10.1007/s12200-013-0367-1

REVIEW ARTICLE

Recent progress of traditional Chinese medical science based on theory of biophoton

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Abstract With the development of biophotonics, biophoton detection technology has been appropriately used. In this paper, the main features and fundamental conceptions of biophotonics were introduced basically. Then the coherence theory of biophoton emission was reviewed. Furthermore, based on this coherence concept, the quantum theory of traditional Chinese medicine (TCM) and properties of Chinese medicinal herbs were presented. To show the nature of biophoton emission in living systems and clarify its basic detection mechanism, high sensitive detection system which allows non-invasive and non-destructive (or less) recording was finally presented.

Keywords biophoton, traditional Chinese medicine (TCM), syndrome, meridian, Chinese herbs, detection technology

1 Introduction

Biophoton emission is defined as ultraweak photon emission, which is originated from living organisms as a result of their metabolic activities. Many living systems have been proved to emit biophoton, such as animals (including their organs, tissues, cells, and even biomacromolecule), plants (including their roots, stems, leaves, flowers and fruits), various kinds of algaes and microbes (bacteria, yeast, etc). Basic characteristics of biophoton emission can be summarized as follows [1,2]: 1) The typical intensity of spontaneous photon emission (SPE) is in the order of 10^{-16} to 10^{-18} W/cm^2, about 1–100 photons/(s·cm^2); 2) The spectrum of biophoton emission is almost continuous within the range of 200–800 nm; 3) The dynamics of biophoton emission presents long-time relaxation after illuminating with light, which is called delayed luminescence (DL); 4) The biophoton emission correlates to many biologic processes and biologic functions; 5) Biophoton emission changes significantly in biologic systems under stress.

In recent decades, the biophotonics has made tremendous progress because of improvement of weak light detection technology and in-depth study of quantum theory of light interacting with matter [3,4], which involves molecular biology, microbiology, biochemistry, quantum optics, thermodynamics, non-equilibrium statistical physics and modern photoelectric detection theory as well as other fields. Research topics include the dependence of biophoton emission on DNA conformation [5], the spectral distribution [6,7], the relevance of biophoton emission with biophysical and biochemical process [8,9], the dependence of biophoton emission on temperature [10], relaxation dynamics of after light illumination [11] and the swarming coherence [12].

From the point of view of molecular physics and quantum theory, biophotons can be considered as biomolecular transition from high-energy state to low-energy state. Any internal changes in biologic systems, either in the components or the structure, will cause the change of microscopic level of the system, resulting in the change of biophoton emission. In 1970s, the Popp's group has done some useful experimental and theoretical research. Their evidence [13] suggests that biophoton has a high degree of coherence. The biophoton emission presents very sensitive response to any internal or external perturbation, which gives holistic information and provides an indicator of integrated effect on a biologic system.

In this paper, we presented the coherence theory of biophoton emission in terms of quantum coherence. Based on such a concept, the quantum theory of traditional Chinese medicine (TCM) and properties of Chinese

Received July 26, 2013; accepted October 16, 2013

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medicinal herbs were presented. Finally, we also investigated the application of biophoton detection technology in living systems, especially in human body, and clarified its basic mechanism. These research results provide experimental evidence for the quantum hypothesis of TCM.

2 Coherence theory of biophoton emission

There are two interpretations about biophoton emission: the biochemical theory [14,15] and the coherence theory [16]. The biochemical theory explains that biophoton is a kind of waste energy in metabolic processes, mainly from radical reactivity of oxidation processes. On the other hand, the coherence theory emphasizes that biophoton emission originates from a coherent nonlinear interaction between weak radiation and collective biomolecules, providing an optimized optical information channel for cellular communication. The interaction can be described by the theory of the quantum optics, thermodynamics, chaos theory, nonequilibrium statistical physics, cavity quantum electrodynamics and cooperative radiation theory. These physical models merge into a theoretical system in terms of quantum coherence mechanism, so the coherence theory is becoming a dominant theory in the biophotonics field.

2.1 Basis of coherence theory

2.1.1 Nonlinearity

A simple summation of the microscopic properties of respective subsystems cannot represent macroscopic properties of a biologic system. Prigogine et al. [17] pointed out that the biologic system is a nonlinear dynamic system subjecting to the theory of dissipative structures. In fact, all the subsystems integrated by a correlation result in a macroscopic ordered complex system, in which the order parameters display a nonlinear dynamics, and nonlinear response depends on physiologic parameters [7]. This phenomenon was demonstrated by the Daphnias' experiment of Galle et al. [12]: the increase of the density of Daphnia led to a nonlinear response of the intensity of biophoton emission, with alternative maxima and minima, instead of a linear increase.

2.1.2 Nonequilibrium

In the biologic system, the spectral distribution follows the rule $f_{(\nu)}$ = constant [16] rather than Boltzmann distribution $f_{(\nu)} = \exp(-h\nu/kT)$, which governs a non-equilibrium phase transition between chaotic field and ordered field. This means that a biologic system is a non-equilibrium system like a continuously pumped laser, and the energy to maintain this non-equilibrium state is from the metabolism. Biologists [18] have found that photon storage in DNA molecules only exists in the excited state because of heaps interaction, while such excited state decomposes in the monomers.

2.1.3 Openness

Living system is an essentially open system, which is maintained by continuous exchange of energy and matter with the environment. Erwin Schrödinger insisted on the importance of a thermodynamic theory of open systems for biologic systems and presented that life depended on the negative entropy for living. If we supply sufficient negative entropy for living systems, we can maintain the system in an ordered state. This view is reflected in the Clausius Carnot inequality in the form of $dS = d_eS + d_iS$ [17], governing the variation of entropy, where d_iS is entropy production inside the system, $d_iS > 0$; d_eS is the flow of entropy from outside. It not only shows how the second law of thermodynamics applies, but also indicates how low entropy and high coherence are maintained.

2.2 Performance of coherent biophoton emission

Subradiance is one of the performances of coherent biophoton emission. In subradiance, no photon is radiated out and photons are considered as a cooperative effect of collective radiators because of quantum coherence [19]. A typical experiment [20] about marine dinoflagellate Pyrocistis elegans has confirmed this phenomenon. Secondly, the biophoton emission transferred through a living system and displayed a high degree of transparency in the spreading of quanta. In fact, a living system is highly organized and its components may be correlated with each other. For instance, when the biophoton stream of cucumber bud goes through a soy cell, there is almost no loss of photon energy [21]. Biophoton emission is considered to be responsible for transmitting bio-information and it has to work with extremely high efficiency in order to guarantee long range correlation and cooperation in the organism. In addition, order effect is also one of the performances of coherent biophoton emission. In Fröhlich' energy storage theory [22], he proposed that metabolic energy was stored in a highly ordered biologic system in the form of coherent electromagnetic vibration rather than as heat dissipation. If we regard a living system as an optical resonator with Q-value, an optimum living state is believed that it has the highest capacity of storing photons (the lowest loss of photons). Popp et al. thought DNA had high capacity of photon storage, in which the Q-value of DNA in cells could reach to 10^{18} or even higher [21]. Moreover, an important characteristic of biophotons is that they follow biologic rhythms [23] (daily, weekly, monthly and annually).

2.3 Formation mechanism of coherent biophoton emission

A biologic system being a typical open system far away from thermal equilibrium, always exchanges energy or matter with the environment. Taking into account the measurement of biophoton emission, combined with the Fröhlich's research model, and basic theories of Haken's synergetics, Prigogine's dissipative structure hypothesis in biology, and the Bose-Einstein condensate, Popp [19] calculated that photons provided the vehicle for which information was transmitted and they transmitted information within a cell and between cells. It is originated from a transition of molecules from high energy states to lower energy states. He postulated a biologic system represented by a coupled oscillator with small damping constant β_ω $(0 < \omega < \infty)$.

He regarded the biophoton emission as a kind of dissipation of living system, like an output light beam of laser. Generally, the laser consists of a resonator cavity, active medium and pump energy. In the biologic system, a cell is analogous to resonator cavity, the adenosinetriphosphate is considered as active medium, and pump energy is from metabolism, which can achieve the population inversion. The difference is that the biophoton emission is an initiative process; on the contrary, the laser is an artificial process.

3 Quantum hypothesis of traditional Chinese medical science and properties of Chinese medicinal herbs based on biophoton

Several studies [24–26] on biophoton emission from the hands have focused on special aspects of TCM. In addition, biophoton emission was discussed in relation to the function of acupuncture meridians [27,28]. According to the theory of TCM, diseases are caused by an unbalance of vital forces called Yin and Yang, which reflects left and right side of body, respectively. In these investigations, the nature of the TCM cannot be presented by the biophoton emission. Based on the biophoton emission coherence theory, the quantum hypothesis of the TCM science and properties of Chinese medicinal herbs is proposed.

3.1 Theory of syndrome in TCM

Modern physics studies found that there are four interaction forces in nature, the strong, weak, electromagnetic interaction and universal gravitation. The strong and weak interactions and universal gravitation are too large or too small to explain internal function of living systems, but electromagnetic interaction plays a decisive role in life. In other words, the various components of living systems, including small molecules, macromolecules, various ions, rely on electromagnetic interaction to cooperate. Therefore, electromagnetic force determines the life phenomenon, and the essence of life's dynamics is electromagnetic interaction. From the point of view of the quantum theory [1], any change in the living system, whether it is in its components or its structure will cause microscopic changes of the system, resulting in biologic electromagnetic radiation.

Some surveys found that changes of external electromagnetic field could cause different biologic effects [29]. For a certain frequency, biologic electromagnetic resonance phenomenon could occur in a specific biologic site. For instance, the visible region of electromagnetic field can cause energy level transitions of biologic macromolecules; the infrared and millimeter-wave region of electromagnetic field can cause vibration and disturbance of biologic macromolecules, facilitating structure conformational change; the extremely low frequency region of electromagnetic field leads to the polarization of biomedium, changing the charge distribution and conduction. These results confirmed the existence of an intrinsic electromagnetic field, and the different physiologic and biochemical reactions corresponding to different electromagnetic frequencies.

TCM theory holds that "qi" is the fundamental phenomenon of life, which has characteristics of materiality, functionality, constant mobility, transformation, and connectivity [30]. The nature of "qi" is the exchange between energy (function) and mass (matter) of organism, which is similar as in Einstein's mass-energy equation. There is no doubt that electromagnetic field exists in the universe and the earth, especially the electromagnetic interaction is dominant interaction force for living systems. The electromagnetic interaction is derived from the exchange of light quantum, which is able to reveal the internal tiny variations of biologic system and demonstrate the weak impact of external environment through detection and analysis of biologic light quantum. This further illustrates that "qi" of TCM can be characterized by the quantum properties of electromagnetic field, depending on quantum theory and electromagnetic theory.

3.1.1 Mathematical model of syndrome in TCM

The coherence theory of electromagnetic radiation within human body provides a basic model to analyze the living system, and this model is called resonator model. For an optical resonator (Fig. 1) [31, page 29–33], Q represents the measure of the capacity of a resonant system to store the energy and can be defined as [31, page 29–33]:

$$Q = 2\pi \frac{stored\ energy}{energy\ dissipated\ per\ cycle}. \quad (1)$$

After mathematical derivation, we can get the formula [32]

$$Sy = \frac{v}{S}, \tag{2}$$

where, ν is the frequency of photon, S is the spectral entropy, Sy is the order state of the living system, that is the quantitative formulation of syndrome in the TCM. It is evident that the order state of living system is related to the emission frequency and system entropy. Under a certain frequency, the order state is only determined by the system entropy.

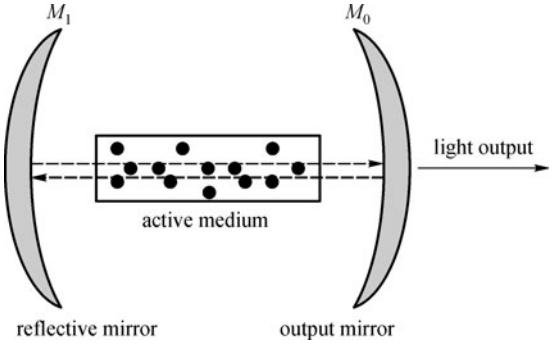

Fig. 1 An optical resonator as the model of biologic system [31, page 29–33]

Figure 2(a) [31, page 36–37] shows the potential energy curve of biomolecular system with exciplex formation. The radiative behavior of such a system can be simplified to a four-level laser, as shown in Fig. 2(b). According to the laser rate equation, the four-level system can be simplified to a three-level system, as shown in Fig. 2(c). According to Dicke's model, the Hamiltonian system with N identical three-level molecules can be introduced, so we solve Schrodinger's equation to obtain a following relation:

$$S(I) = \ln(6I + 1). \tag{3}$$

This is mathematical model of biologic order state (syndrome in TCM). Substituting Eq. (3) into Eq. (2), we can get the following new equation:

$$Sy = \frac{v}{\ln(6I + 1)}, \tag{4}$$

where Sy is the order state of the living system, or in other words, it is the quantitative formulation of syndrome in the TCM; v is the frequency of electromagnetic radiation and I is the intensity of electromagnetic radiation within the human body.

3.1.2 Theory of heaven-human correspondence

The living things on the earth exist in the spatio-temporal electromagnetic field, which can be considered as "qi" of the world. Spatio-temporal electromagnetic field makes the universe connect with tissues, organs, and meridians of human body together, and it is called as "heaven-human correspondence." The "heaven-human correspondence" means that it is a resonance interaction between human bodies' electromagnetic field ("qi" of human body) and the spatio-temporal electromagnetic field ("qi" of the world). Figure 3 shows the relationship between terrestrial magnetism activity ($\sum Kp$) and disease morbidity, which reflects the view of "heaven-human correspondence" [33,34].

3.1.3 TCM viscera picture theory

Since the mutual interference characterizes the electromagnetic fields induced by the electromagnetic radiation within human body, the quanta of the fields have the function of information transference, operating as an informant for communicating information between tissues, organs, cells, and biologic molecules, etc., and playing an important role in transferring information for life movements [35]. Therefore, the quanta of human body are the

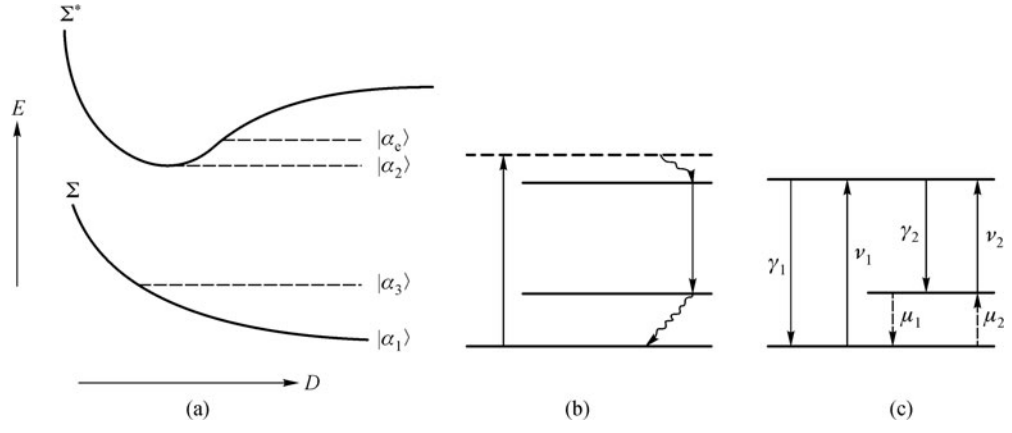

Fig. 2 Energy level structure of exciplex system. (a) Potential energy curve of biomolecular with exciplex formation. "Σ*" represents the bond excited state and "Σ" represents the repulsive ground state. "E" denotes energy and "D" denotes distance of monomer; (b) four-level model; and (c) three-level model [31, page 36–37]

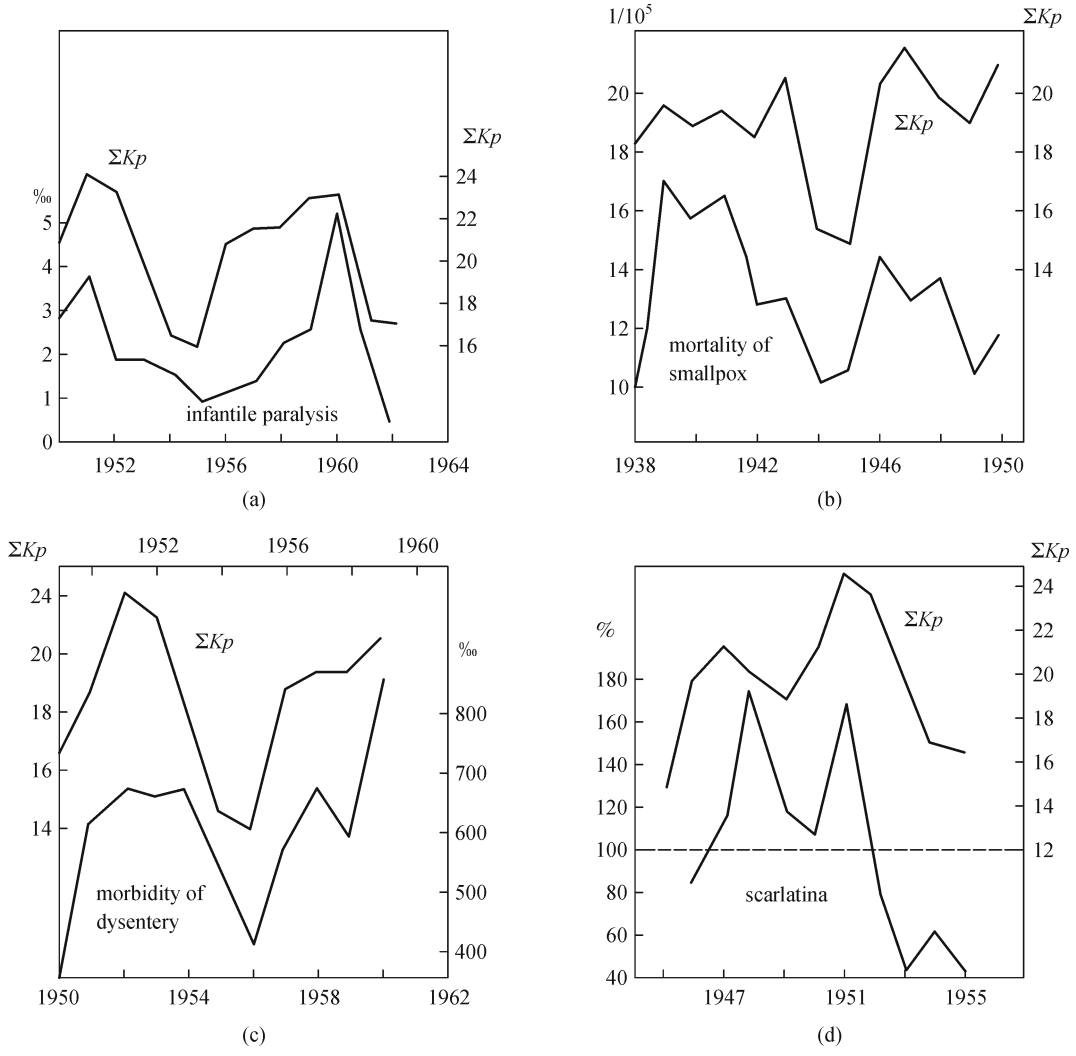

Fig. 3 Relationship between terrestrial magnetism activity ($\sum Kp$) and disease morbidity. (a) Morbidity of infantile paralysis in Japan; (b) mortality of smallpox in Australia; (c) morbidity of dysentery in the world; (d) morbidity of scarlatina in Leningrad [34]

"qi" informant for the regulation and adjustment of the viscera network in TCM.

3.1.4 Treatment based on syndrome differentiation

A biologic system under external energy constantly pumps, always being in a state far from thermal equilibrium, radiates biophotons to achieve dynamic balance. In fact, this is a non-equilibrium steady-state. A biologic system will deviate from steady-state, and show special physiologic reaction in the face of adversity. The core of syndrome differentiation is state by the process using physical or chemical method to correct the deviation state to the normal state. This "state" is a symptom, which is the quantum superposition state formed with body's electromagnetic radiation. We think: under pathological state, quantum superposition states of human electromagnetic radiation field are different from that in the healthy situation. Syndrome differentiation is to adjust quantum superposition states of electromagnetic radiation field to a healthy situation.

3.2 Theory of channels and collaterals

The meridian is one of the important components of TCM, which has achieved much progress in clinical applications in recent years [36,37]. TCM believes that meridians link blood and internal organs with body surface and other parts, acting as the channels for "qi" and transporting substance, information or energy to strive for balance between the organs. Some surveys found that the meridian has low resistance regions in the body shallow surface of healthy human.

We can consider the cell or a human body as a small spheric resonator, in a spherical coordinate system (Fig. 4) [30]. If coherent rays radiated by any two random points (molecules, cells, etc.) A, B produce interfering effect, the interference fringe will be generated on any point C of the

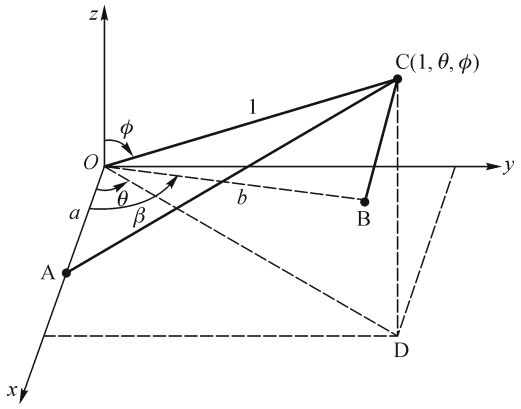

Fig. 4 Spherical coordinate system [30]

sphere. An interference curve is shown in Fig. 5, maxima of interfering effect occur in a certain value, and both the region $\pi/2 \leqslant \Phi \leqslant \pi$ and region $0 \leqslant \Phi \leqslant \pi/2$ are symmetric with respect to $\Phi = \pi/2$ [30].

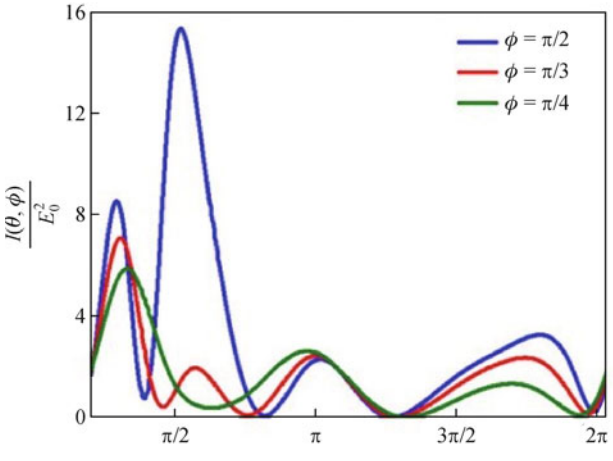

Fig. 5 Value calculation of three-dimensional observation [30]

It can be inferred that the coherent electromagnetic radiation field of human body causes an interference effect and the interference fringe (meridian) is produced on the body surface. According to the theoretical arithmetics of such simplified model, a rough calculation of the interference fringe distribution and meridian interval is consistent with the idea that body interference phenomenon, and coincides with the meridian. The spheric cavities have high radiation (photon) field that induce various nonlinear effects and non-local coherent radiation. Yan et al. [38] randomly selected 158 persons to test high luminescence of skin surface, finding that 14 high light lines of the human body surface coincided with 14 meridians.

The photon radiation field inside the organism can generate strong interference phenomenon, which leads to the following 'channels and collaterals hypothesis': the photon radiation field within the human body is characterized by non-local interference, resulting in the interfering phenomena throughout the human body. The interfering beams form a whole network of solidarity, distributed beams of varied intensity on the surface of body. The beams are channels and collaterals. They carry the corresponding biologic information and link tissues and organs within the body.

A meridian line has two endpoints, one end is on a finger (or toe) tip acupoint and the other end communicates with a certain organ in the body. The different acupoints connect to different organs [31, page 307–310], so biophoton emission from human finger acupoints carries a wealth of information about internal organs. Figure 6(a) [31, page 307–310] depicts photon emission intensity of one patient's fingers with acute bronchitis: biophoton emission of left-right thumb occurred serious asymmetry, since the bronchitis is related to lung channel according to the theory of TCM. After eight days' treatment, the patient recovered, and photon emission intensity of all fingers dropped significantly and asymmetry disappeared (Fig. 6(b)).

3.3 Quantum hypothesis of properties of Chinese medicinal herbs

Based on the view that the electromagnetic radiation within the organism represents the "qi" in TCM theories, the quantum hypothesis of properties of Chinese medicinal herbs is presented. The four properties and meridian tropism are the core concepts of properties of Chinese medicinal herbs. The four properties are parameters that regulate the quantum superposition state of organism electromagnetic field; meridian tropism indicates a match between the electromagnetic radiation frequency in medicine-organism interaction and the organism's meridian (frequency of electromagnetic radiation beam); five flavours and ascending, descending, floating and sinking are aggregative indicators of properties of Chinese medicinal herbs.

Using cold, hot, warm and cool properties of drugs to adjust the unbalance of a human body, drugs and its corresponding target molecules within the body can produce chemical or physical reactions. These reactions make biomolecules' component or structure change, causing the organism to change at microscopic level, which is basically understood as mutual transitions of high-low energy states of biologic molecules. The energy released in this process is bio-electromagnetic radiation. This electromagnetic radiation and some parts of original electromagnetic radiation within body will resonate. If the frequency of the electromagnetic wave is the same as the frequency of the electromagnetic field of a certain meridian, Chinese medicinal herbs can affect this meridian and through this meridian regulate tissues and organs of human body. In other words, it can affect the superposition

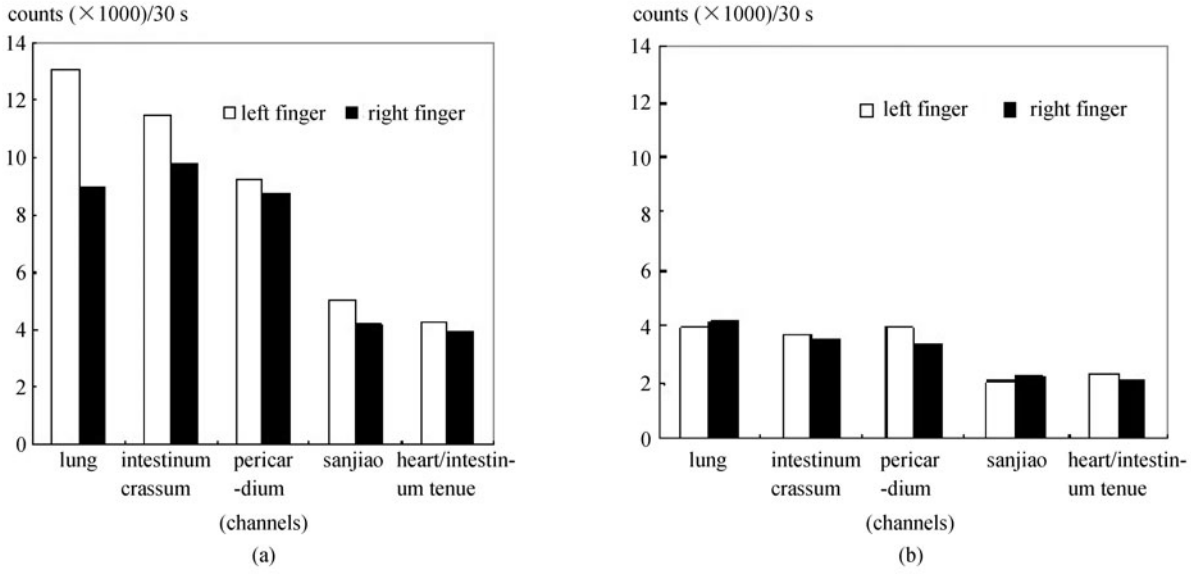

Fig. 6 (a) Photon emission intensity of one patient's fingers with acute bronchitis; (b) photon emission intensity of fingers after eight days' treatment [31, page 307–310]

states of electromagnetic field of organism, which makes body's electromagnetic field deviation from the normal state to return to normal [39].

4 Application of biophoton detection technology

The development of photomultiplier tube and charge-coupled device (CCD) imaging technology facilitated the development and application of biophoton detection technology. Compared with traditional analysis methods, biophoton detection technology could be more useful as a sensitive non-invasive method to obtain the samples' holistic information and provide an indication of the global and integrated effects on a biologic system. Many researches [40,41] also show that biophoton detection technology has been successfully applied to human detection field.

It is well known that agriculture is the pillar industry of the national economy and food hygiene is closely related to human health. By means of biophoton detection measurement, quality inspection and performance analysis of various types of plants, seeds and foods have been carried out in depth. Food was measured including cooking oil, powdered milk, alcoholic drink, eggs, fruits, and other biologic products [42,43]. And performance analysis of plants and seeds by biophoton detection have achieved fruitful results. For example, Winkler et al. have detected ultraweak and induced photon emission after wounding cucurbita pepo [44], and Komatsu's group [45] has done a series of studies on soybean under flooding and drought stresses. Experiments showed that wounding significantly changed the biophoton emission from a stable to an unstable state.

Furthermore, an important application of biophoton detection technology is human health testing and tumor diagnosis [46–48]. The characterization of human biophoton emission suggests that it has potential application in clinical examination. Some results show a tendency that spontaneous photon emission provides more photons from normal tissues than from tumor tissues, while tumor tissues, such as adenocarcinoma, squamous cell carcinoma, hepatocellular carcinoma and esophagus cancer tissues, have more photon emissions than the corresponding normal tissues in delayed luminescence. In early 1990s, Musumeci [7,49], Inaba [50] and van Wijk [40,51] research groups have studied biophoton emission from human normal and tumor tissues, which gives great inspiration to later researchers.

In addition, the technology provides a high sensitive and stable measurement system for the body (including fingers, toes, acupuncture points) surfaces' photon emission. van Wijk et al. [25,41] have performed a series of researches on spontaneous photon emission from human hand and other different body sites. It is found that photon emission intensity of different regions is different and can change in one day, especially the left and right hand. Park et al. [52] detected biophoton emission from human hand before and after magneto-acupuncture stimuli. Significant differences were also observed between stimulated and non-stimulated acupoint. Kim et al. [53] also detected biophoton emission from the center of fingernails and fingerprints of human. The difference of radiation intensity from various body

sites reflects the different human health state. These researches provide experimental evidence for the quantum hypothesis of TCM.

5 Conclusions

Biophoton emission from a variety of living organisms has been reviewed. Based on theoretical basis of quantum theory and modern science, the quantum theory of TCM and properties of Chinese medicinal herbs, including the theory of syndrome in TCM (such as "heaven-human correspondence", TCM viscera picture theory and treatment based on syndrome differentiation), the theory of channels and collaterals and the quantum hypothesis of properties of Chinese medicinal herbs, are presented. The biophoton analysis techniques could give entire information about biologic effects of living organisms caused by internal changes and environmental impact. The overall reaction of life' state is symptoms in TCM. We would like to use quantum theory to achieve scientific conversion of TCM theory and establish quantitative examination system in medical experiments.

Acknowledgements This work was supported by the National Natural Science Foundation of China (Grant Nos. 81273997 and 61106059).

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