Biophoton Emission from the Hands

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Biophoton emissions from the palms and the backs of the hands were measured for twenty healthy subjects. About 34% more biophotons (in the range of 300-650 nm) were observed from the hands than from the background, but no significant difference was observed between the palms and the back of the hands. No marked dependence on age or gender was found. Photo-counting statistics were analyzed to study the coherence of biophotons, and the measured biophotons from the hands lacked the usual coherence because of the large area and the long measurement time.

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I. INTRODUCTION

Ultraweak light emission from tissues for all living systems has been discovered by many researchers in Russia, Australia, Germany, Poland, Italy, USA, China, and Japan by using modern photomultiplier techniques [1]. Even though there is no agreement about the interpretation of this phenomenon, the hypothesis by Popp offers a very challenging view: The biophoton emission is due to coherent photon fields within the living system, which provide intracellular and intercellular communication that regulates biological functions like cell growth and differentiation, healing injury, and other biochemical activities [2]. Much supporting evidence exists for the hypothesis. Distribution of biophotons shows Poissonian photocount statistics (PCS) [3], and delayed luminescence (DL), which is the fluorescence of a living system after exposure to light illumination, follows a hyperbolic-like relaxation function rather than an exponential one, which indicates a fully coherent field [4]. Recently, further evidence of the quantum nature of biophotons was reported by Popp *et al.*, who found the photocount statistics of squeezed states in a living system [5]. The source of biophoton emission can be traced back to DNA [2,6].

Applications of biophotons to agriculture, environmental studies and other industrial purposes has been widely explored, and their medical use could be of great value [7]. Also, some efforts exist to measure biophotons from human skin [8]. One of the earliest measurements was by Bieske *et al.*, [9] in the summer 1998, and more recent ones are by Chevalley *et al.* [10] and by Nakamura and Hiramatsu [11]. These measurements were done in different conditions for various purposes and call for similar experiments to form a set of data as a basis for medical applications and theory construction.

In this paper, we report on measurements of biophotons from the hands, comparing the emission rates from the palms and the back of the hands. We also compared teen-age subjects, twenties, and older subjects, and found no noticeable differences. There is no significant differences between male and female subjects, either. The emission rate from the back of the hand was measured by Bieske *et al.*, and our data are in good

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agreement with theirs [9,10].

In our experiments, we took only normal subjects without any specific disease, and the data will be useful as a reference for diagnostic purposes when an unhealthy subject's biophoton emission is studied, for it is known that unhealthy people emit more biophotons [8]. Another possible application is to evaluate the function of acupuncture meridians because there are suggestive reports on the correlation between biophoton emission rates and the conditions of the meridians. The present report might be useful in future research on objective diagnosis of acupuncture meridians, which are basic elements of traditional Chinese and Korean medicine.

II. MATERIALS AND METHODS

Experiments were done in a dark room with a dark chamber and a photomultiplier tube(CR120, Hamamatsu, Beijing) with a sensitivity within the range of 300 to 650 nm and an active diameter of area of 44 cm. The room temperature was somewhat cold (10 °C ± 1 °C), and the measurements were done during daytime, 12-18 pm, for two days.

Twenty healthy subjects, whose mean age was 24 years (range from 14 to 56), participated in the biophoton emission measurements voluntarily. None of them had any history of serious disease.

Each subject entered the dark room, cleaned his or her right hand with alcohol-soaked cotton, and dried it for five minutes. Before the subject inserted the right hand into the dark chamber, the dark count inside the chamber, was measured for one minute; then, the right hand was inserted into the chamber, and put at the side of the PMT so that it was located below the top surface of the PMT. For all the measured subjects, the dark counts with and without the hand at the side showed little difference, 0.45 ± 0.46(cps) difference between the two kinds of measurement.

After the two background measurements, the palm was placed on the top of the PMT for one minute; then, the hand was put beside and below the PMT. The next step was to put the back of the hand on the top of the PMT. We repeated once more the measurement of the palm and the dark count as a final measurement. In brief, the measuring steps are organized as follows:

Alcohol cleaning and dry (5 min) → dark count (1 min) → HSB (1 min) → palm (1 min) → HSB (1 min) → Back of the Hand (1 min) → HSB (1 min) → palm (1 min) → HSB (1min) → dark count (1 min),

where HSB is the abbreviation for the hand put beside and below the PMT. We repeated the HSB measurement in order to insure the stability and reliability of the dark chamber system, and we finally checked the dark count once more to make sure it was still the same as the initial measurement.

The palm and the back of each subject's right hand were placed on top of an IR filter which was, in turn, placed on the top side of the PMT. We requested each subject to cover the top side of the PMT with the palm or the back of the hand such that the fingers were outside the circular boundary of the PMT. We found that the dark counts and the HSB counts were fairly stable and that our measuring system was quite reliable; no background light was entering the dark chamber.

Table 1. Average biophoton counts per second. The first five subjects are females, and the rest fifteen are males.

	DC1	HSB1	Palm1	HSB2	Back	HSB3	Palm	HSB4	DC2
1	30.1	28.6	43.9	33.4	44.9	31.9	44.6	34.6	32.2
2	29.4	30.2	43.8	31.8	40.2	29.1	47.8	29.7	29.1
3	30.9	30.6	37.4	31.9	38.6	31.2	36.9	31.2	30.7
4	31.5	32.6	41.9	30.8	41.6	32.7	39.1	31.7	31.6
5	29.2	31.1	45.0	33.1	39.7	33.9	46.3	32.1	32.6
6	31	31.8	41.5	31.3	44.0	31.7	42.7	32.5	31.8
7	31.0	29.6	45.7	33.1	41.0	33.1	44.2	33.7	32.9
8	33.3	31.7	46.9	33.1	39.4	34.4	44.9	35.2	35.3
9	29.7	29.7	39.9	30.5	36.4	30.7	39.4	32.0	31.6
10	33.5	31.8	40.2	33.0	41.5	33.0	37.9	32.4	30.7
11	28.1	28.9	35.8	29.4	34.8	29.9	35.5	30.6	30.7
12	32.4	33.6	46.0	33.9	44.0	33.2	47.1	34.8	33.0
13	30.6	31.6	35.1	29.4	38.3	29.1	37.6	29.6	28.9
14	30.5	30.8	42.1	32.1	36.0	30.9	40.0	30.8	31.1
15	31.4	30.8	35.4	28.9	34.6	29.9	35.0	30.6	28.9
16	30.2	29.8	38.5	32.4	36.3	29.6	36.7	31.5	30.1
17	30.1	29.9	46.9	29.9	42.7	29.7	46.0	29.1	30.2
18	29.7	29.2	32.4	27.3	31.0	29.9	31.9	30.0	29.6
19	32.4	31.3	41.7	30.9	40.4	31.6	45.3	33.9	32.6
20	30.2	28.0	53.0	29.7	43.8	28.6	55.3	31.5	30.5
$\langle n \rangle$	30.8	30.6	41.7	31.3	39.5	31.2	41.7	31.9	31.2
σ	1.37	1.42	5.00	1.79	3.72	1.74	5.64	7.80	1.61

III. RESULT AND DISCUSSION

The average biophoton counts per second is presented in the Table 1 for the twenty healthy subjects. The dark count is

$$n_{d1} = 30.8 \pm 1.36, \ n_{d2} = 31.2 \pm 1.61, \tag{1}$$

where n_{d1} and n_{d2} are the average dark counts with standard deviations over the twenty cases before and after the hand measurement, respectively. We see that the system of the PMT and the dark chamber is reliable, for there is no difference between the two averages within the statistical significance ($p < 0.05$).

The average background counts when a hand is inserted into, but remains beside and below the

PMT(HSB), were measured four times to check the measurement process throughout the experiments. The data are

$$n_{HSB1} = 30.6 \pm 1.41, \;\; n_{HSB2} = 31.3 \pm 1.79 \quad (2)$$

$$n_{HSB3} = 31.2 \pm 1.74, \;\; n_{HSB4} = 31.9 \pm 1.61, \quad (3)$$

which shows that inserting a hand into the dark chamber did not produce any noticeable change from the dark counts. ($p < 0.05$)

The data for the palm were measured twice:

$$n_{palm1} = 41.7 \pm 5.00, \;\; n_{palm2} = 41.7 \pm 5.64, \quad (4)$$

and were the same ($p < 0.05$). Photons are clearly being emitted from the palms, and the number of photons was about 34 % higher than the dark counts:

$$\frac{n_p}{n_d} = 1.34 \pm 0.166. \quad (5)$$

Furthermore, the variations among the healthy people were not large, for the largest deviation was about 25 % of the average value. Unhealthy people showed more than 100 % larger emission [8]. Thus, we can use this value as a reference to evaluate a person's health condition because unhealthy people are known to have higher rates of biophoton emission [8].

The data for the back of the hand are

$$n_{BH} = 39.5 \pm 3.73. \quad (6)$$

We note that the biophoton emission from the palm and the back of the hand are similar

$$\frac{n_{BH}}{n_{palm}} = 1.05 \pm 0.083, \quad (7)$$

where the statistical significance is tested by the t-test ($p < 0.05$), which is also a useful reference quantity for healthy people. Unhealthy people with Yang-qui deficiency could show less biophoton emission from the back of the hand [12]. Thus, this measurement could be used as an objective diagnosis for the Yan or Yin qui indicator of oriental medicine.

There are three age groups of subjects, those in their teens, theose in their twenties, and those over thirty. The average biophoton emissions are

$$n_{teen} = 42.4 \pm 3.31, \quad (8)$$

$$n_{twenty} = 39.7 \pm 4.15, \quad (9)$$

$$n_{>thirty} = 44.4 \pm 7.55, \quad (10)$$

which show that there is no apparent age-dependence in the biophoton emission rate. For statistically meaningful statements, one would certainly need larger samples. We have not measured children below ten years of age or older people over sixty, where the biophoton emission rate might possibly be different.

There is no male-female dependence. Among the participants were fifteen males and five females, and their biophoton rates are

$$n_m = 41.4 \pm 5.69, \quad (11)$$

$$n_f = 42.7 \pm 3.75. \quad (12)$$

This is not a sufficiently large sample, therefore, it is only considered as a suggestive observation.

By applying photon-counting statistics, one can study the degree of coherence of biophoton emission [3]. It is wellknown that for random or thermal photons, one has geometrical probability distribution:

$$P_m(\Delta t) = \frac{1}{1+\langle n\rangle}\left(\frac{\langle n\rangle}{1+\langle n\rangle}\right)^m, \quad (13)$$

where P_m is the probability of finding m-photons, and $\langle n\rangle$ is the average number of photons in the gate-time Δt. Black body radiation for a single mode satisfies the geometric probability distribution. For multimode thermal radiation, the distribution changes to

$$P_m(\Delta t) = \frac{1}{\left(1+\frac{\langle n\rangle}{M}\right)^M}\left(\frac{\langle n\rangle}{M+\langle n\rangle}\right)^m {}_{m+M-1}C_m, \quad (14)$$

where M is the number of modes.

In the case of a fully coherent light, the probability $P_m(\Delta t)$ of registering m photons within the time interval Δt is Poissonian for all values of M:

$$P_m(\Delta t) = e^{-\langle n\rangle}\frac{\langle n\rangle^m}{m!}. \quad (15)$$

One should note that with increasing M, the geometrical distribution approaches the Poissonian distribution. Hence, the agreement of $P_m(\Delta t)$ with a Poissonian distribution indicates either a coherent or a high M-value random photon emission.

As a measure of agreement with the Poissonian distribution, it is usual to take the value

$$\delta = \frac{\sigma^2 - \langle n\rangle}{\langle n\rangle}, \quad (16)$$

where σ^2 is the variance. For the geometric distribution of a single mode, one has

$$\delta_{random} = \langle n\rangle, \quad (17)$$

while for M-modes,

$$\delta_{M-mode} = \langle n\rangle/M, \quad (18)$$

and for a Poissonian distribution

$$\delta_{Poisson} = 0. \quad (19)$$

One good example of the probability distribution $P_m(\Delta t = 0.1s)$ is shown in Fig. 1. It looks somewhat close to the Poissonian distribution. However, the other samples are not so nearly Poissonian. To show this more quantitatively, the $\delta - values$ for the three measurements (dark count1, palm1, back of the hand) are presented in Fig. 2 for the time interval $\Delta t = 0.1s$. Fig. 2 shows that the dark counts and the biophotons from either the palm or the back of the hand have similar $\delta - values$. The average $\delta - values$ are

$$\delta_{darkcount} = 0.333 \pm 0.228, \quad (20)$$

$$\delta_{palm} = 0.303 \pm 0.253, \quad (21)$$

$$\delta_{backhand} = 0.286 \pm 0.285. \quad (22)$$

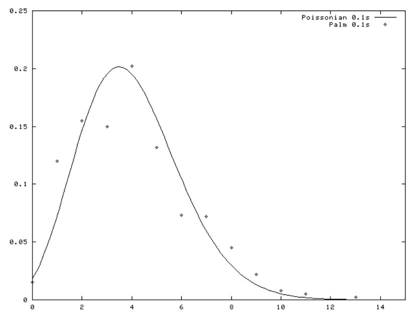

Fig. 1. Photocount probability distributions compared with a Poisson distribution. The distribution consists of 600 samples from a subject's palm with a gate time 0.1s.

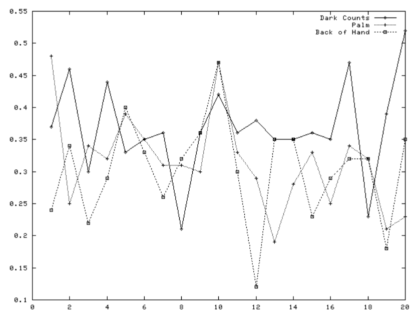

Fig. 2. Degree of non-Poissonian distribution of twenty subjects for the dark count and for emissions from the palms and the backs of hands. The δ-values are of a random nature.

These $\delta - values$ are rather far from the Poisson distribution, compared to the previously reported values for the cucumber seedling [3,6,13], but we note that the δ-value for the dark count is in good agreement with the value reported in another work [3].

Even though it is known that biophotons exhibit a Poissonian distribution due to the coherence of the source, we found that the measured biophotons from the palm and the back of the hand were not coherent, because the area of the biophoton source was too large to be coherent (a circular area with a diameter of 44 mm), and during the measurement time (one minute) the hand may have vibrations and movements that introduced random effects. In order to improve the coherence study through the photo-counting statistics, one needs further improvements such as localizing the photon source, narrowing the photon spectra, and restricting hand movements.

One might wonder whether biophotons from the hands might be thermal radiation from the hands. The spectral response of our PMT is from 300-650 nm; thus, infrared emission is not detected by our system. In order to make sure of this point, we put an IR filter (cut-off = 800 nm) on the top of our PMT and compared the data with and without the IR filter. We found no noticeable difference in the average photo counts, which confirms the non-detection of thermal photons by our PMT.

Only few groups have measured biophotons from the hands. Our data are not directly comparable with theirs [9–11] because of different measuring conditions such as the PMT characteristics, the photon-emitting positions, areas, the subjects, and the environment. Nevertheless, the average photon counts are of the same order, and we hope that as more data accumulates, it could be used as a reference for health-evaluation programs and for diagnosis in comparison with other biosignal measurements [14].

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