Biophoton emission of a lichen species *Parmelia tinctorum*

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The properties of biophoton signals emitted by samples of lichen species *P. tinctorum* are investigated. The shape of a light induced signal is determined from 5ms onwards using successively the bin resolution of 1, 10 and 100 ms; 1000 measurements in successive bins are made at each resolution. The measurement of the shape is repeated at various temperatures in the range (3°C-40°C) in steps of 1°C. It is found that a biophoton signal is very sensitive to temperature and different portions of the signal show different sensitivity. The temperature dependence of the decaying part is even qualitatively different from that of the non-decaying part. The signal responds to temperature changes of 0.1°C in less than 1 ms. The effect of monochromatic stimulation on the strengths of the signal and its red, blue and green spectral components are determined in the wavelength range (400-700) nm in steps of 10nm. The signal and its broad spectral components have similar excitation curves. The relative strength of spectral component appears independent of the stimulating wavelength.

The shape of the decaying portion of the signal and its red, blue and green components is also determined. The characteristic of decay in all four cases is non-exponential. The measurements with various interference filters spanning the entire visible region are made with the bin size of 20s. These measurements are qualitative because of large fluctuations but suggest that the spectral components of a biophoton signal are distributed in the entire visible region. The probabilities of detecting different number of photons in the non-decaying portion are determined by making 30000 measurements in each set with the bin size of 50, 100, 200, 300, 400, 500 and 700 ms. The probabilities determine the parameters of a squeezed state of light; the magnitude of its displacement parameter is different but the phase of its displacement parameter and its squeezing parameter are same for different sizes of a bin. These measurements further indicate that the average signal strength remains constant for 19 hr.

**Keywords:** Biophoton emission, Lichen, Decay character, Excitation curve, Spectral components, Temperature dependence, Squeezed state

Lichens are naturally occurring quasi-stable living systems that do not show any appreciable growth or deterioration over a period of few weeks in normal laboratory conditions. It is, therefore, possible to consider the measurements of properties made over a period of a few hours to correspond to a single biophoton signal emitted from a physiological state of a sample of lichen. A physiological state is characterised by metabolic activities, which in the lichen sample depend upon the water content. The two physiological states are easily identifiable in lichen samples. These are wet and dry states. The wet state is fully saturated with water; a sample attains wet state within 5 min of soaking it with water in most lichen species. The sample in its dry state has only a minimal amount of water needed for its survival. The sample attains its dry state because of the evaporation of water in a time depending upon the environmental conditions. A wet sample becomes dry in a few days in its natural habitat, in nearly 24 hr in normal laboratory conditions, and in a few minutes in front of hot air blower. The rate of evaporation is much slower in a closed cuvette, where a sample remains in the same physiological state for more than 24 hr. The unique feature is that a sample of lichen can remain in a dry or wet state for weeks and the transition between these states is reversible and controllable by external means. These states have different metabolic activities—minimal in the dry state and at an enhanced rate in the wet state. Lichen sample emits biophoton signal of different strength in these states; the signal is very weak in the dry state and very intense in the wet state. A dramatic change in the light induced signal of a dry lichen sample occurs by the addition of a drop of water to the sample. The change is reversible and externally controllable; it is correlated with the transition between physiological states. The biophoton signal appears to be a property of the physiological state.

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Perhaps, there is a link between metabolic activities and biophoton emission\textsuperscript{3,4}. The measurability of a biophoton signal suggests the possibility of measuring metabolic activities. The aim of the present study is to prepare the ground for this possibility by exploring the holistic behaviour of biophoton signals.

Biophoton signal is a photon signal of unknown origin emitted by almost all living systems\textsuperscript{5}. Its characteristic shape identifies it. The emitted photons are mainly in the visible range. Exposure to visible light stimulates a living system and induces it to emit a biophoton signal with two distinct portions—decaying and non-decaying. The decaying portion is of small duration and its character is non-exponential. The non-decaying portion that has large fluctuations and is observable throughout the lifetime of a system follows it. The decaying part is called stimulated or light induced biophoton signal and the non-decaying part is called spontaneous biophoton signal. The duration of decay in the signals of lichens is around 200 s. The shapes of these signals were earlier studied in the region (3-200 s) in many species of lichens\textsuperscript{5,6}. The present study extends the region to (5 ms-20 hr). The shape was determined by progressively increasing the resolution of a point from 1ms to 20s. In addition, the decay behaviour of broad spectral components, the effects of monochromatic stimulation, and the temperature dependence of strength of stimulated biophoton signal as well as the photo count statistics of a spontaneous biophoton signal have been determined using photo multiplier detectors in single photon counting mode. These measurements provide a direct evidence for the holistic nature of biophoton signals. These measurements were made in eight different lichen species. The gross features of biophoton signals are similar in different species though specific values differ. The gross features point towards the holistic nature. The gross features and their implications are brought out in this paper by using the specific values obtained from the samples of the species Parmelia tinctorum only. The species is available in abundance and we could repeat the measurements many times in the last five years.

Materials and Methods

Lichen samples were collected from the forests around Shillong, India in the first week of July under the supervision of a lichenologist who also identified the species. The temperature of the natural habitat varies in the range (1\textdegree-30\textdegree C) and there is plenty of rainfall throughout the year. The collected samples were stored in polythene bags without detaching the substrates. The measurements were made in the months of August and September in Neuss, Germany. The collection of samples and measurement of biophoton signals were repeated for five years from 1998 to 2002. Any set of measurements utilised only a small portion of the collected sample and the portion was thrown away after the measurements.

The measurements were made with two measuring systems, called PMS1 and PMS3. Each one of these systems has a photon detecting unit, a sample chamber, a device for inserting filters, a light source for stimulation and associated electronics. The photon-detecting unit is a photo multiplier tube EMI 9558 QA, kept in a sealed enclosure and cooled to -30\textdegree C in both systems. The unit detects photons that enter through a thin window into the detecting enclosure. The window of the detecting enclosure faces another window of the sample chamber. Both systems have a provision for inserting a filter in between these two windows. The number and types of filters available for insertion are different in the two systems. PMS1 has a rotating wheel with 22 possible positions for filters. Eleven interference filters with peak transmission at different wavelengths in the range 246.6-850 nm, seven long pass filters in the range 268-715 nm, and three band pass filters are fixed in twenty one positions leaving one position empty for measurements without a filter. The selected filters can scan the transmission in the entire visible region through 30 nm wide windows. PMS3 has only four possible positions. One position is empty and other three positions have a red, a blue and a green band pass filter. The sample chamber is a light tight metal container with negligible photon emission. It can be opened for putting and removing a sample(s). The sample for measurements is put in a sample holder that is a quartz cuvette. The sample chamber is of different designs in the two systems. The sample chamber of PMS1 is small and has two windows; one for the entry of stimulating light and the other for the exit of biophotons. Two shutters control the passage of radiation through these windows. A lamp produces white light of definite intensity for stimulation for a pre-determined period and the biophotons emitted after 5ms of stimulation are detected. The delay of 5ms eliminates the fluorescence signals excited by the stimulation of light. A computer programme controls the stimulation and measurements. The stimulation time is fixed to in seconds and it was 5s in our measurements. The system registers the number of
photon detected in a bin of fixed duration. The duration is called dwell time or bin size and can be fixed to any value from 1μs to 99μs in steps of 1μs. The system can register the counts detected in successive bins up to a maximum of 64000. The sample chamber of PMS3 is bigger; it has only one window facing the detector. The base of the sample chamber is a turntable with a provision to put 16 sample holders at different positions. Each position has a black enclosure with openings at one side and at the top. The measuring position is near the window facing the detector and any one of the 16 samples can be brought to the measuring position by rotating the turntable. The sample placed at the measuring position can be stimulated from the top by the light from an optical cable. A monochromator produces monochromatic stimulating light of bandwidth 10nm around a wavelength adjustable in the range 400-700 nm. The monochromator also produces white light in its one setting. A computer programme controls the parameters of stimulation and measurements. The inputs of the programme are range and increment of the wavelength of stimulation, time of stimulation, dwell time, filter, number of samples and number of repetitions along with the delay time between them. The programme can register only the number of photons detected in 256 successive bins. The programme first registers the background photon emission from the sample; it then stimulates the sample and makes measurements of stimulated biophoton signal in any measurement. The programme is capable of repeating the above sequence after each alteration of wavelength of stimulating light and after every change of sample position. Both systems have an arrangement for regulating the temperature of sample chamber from 1°C to 40°C. The temperature at the bottom of the cuvette is measured through a sensor. The regulating unit could change the temperature by 1°C of the sample chamber at different temperatures in a time ranging from 5 to 15 m in PMS1 and from 15 to 2 hr in PMS3. PMS1 was for determination of the shape, temperature dependence of strength, and photon count statistics and PMS3 for the determination of the relative strengths of red blue and green components of a signal and their dependence on the wavelength of stimulation. Stability of the physiological state was ensured by checking the strength of stimulated biophoton signal at the beginning and end of every set of measurements.

Results
Our measurements reveal four important features of biophoton signals. A brief description of these features and the procedure adopted in their determination is given below:

*Shape of the signal*—The shape of stimulated biophoton signal emitted by a lichen sample has been determined 5ms after the stimulation. The sample was kept in the sample chamber for 5m before the measurement; it eliminated all decaying contributions induced by exposure to laboratory illumination. A programme then made the following measurements:

1. Measurement of photon counts in 1000 successive bins of 1ms duration of the signal emitted before stimulation;
2. stimulation of the sample by white light for 5 s;
3. measurement of photon counts in 1000 successive bins of 1ms duration of the stimulated signal;
4. continuation of the measurement of photon counts in 1000 successive bins of 10ms duration of the stimulated signal;
5. continuation of the measurement of photon counts of stimulated signal in 1000 successive bins of 100ms duration of the stimulated signal;
6. pause in measurements for 5 m; and
7. repeating the above cycle of six steps for three times.

The programme detects three successive portions of 1, 10 and 100 s durations after stimulation using bins of size 1, 10 and 100 ms respectively. Fig. 1 depicts

![Fig. 1 — Stimulated biophoton signal emitted at 4°C. The number of counts/ms is plotted as a function of bin number in three successive portions of a signal. The duration of a bin was 1, 10 and 100 ms in these successive portions. The data points of these portions are represented respectively by the symbols (●), (○), and (▲). The data points are plotted after every five bins for the clarity of presentation.](image-url)
these portions of a biophoton signal observed at 4°C. Every fifth data point observed in the first cycle is plotted in the figure for the sake of clarity. The count rate beyond these portions shows noisy behaviour for a long time. The noisy behaviour has been observed for 19 hr in the determination of photo count statistics. The figure is a semi-log plot and it does not have any prominent straight-line portion. The absence of prominent straight-line portion implies a non-exponential decay character of the signal. Coarser resolutions with dwell time of 1, 3, and 10 s produce signals of similar shapes and decay character. Both non-exponential decay and absence of decay are anomalous features of biophoton signals and require a holistic description implying correlation among photon emitting units.

The temperature dependence of signal strength—The biophoton signals emitted at various temperatures in the range (1°C-40°C) were determined using the programme and sample of the previous subsection. The sample chamber was first cooled to 1°C and the measurements were made after 15 m. The temperature of the sample chamber was raised in steps of 1°C and the same procedure was followed in the measurements at all temperatures in the range. The biophoton signal shows strong temperature dependence; even the signals emitted at temperatures differing by 1°C are different. One needs a procedure to quantify this difference because biophoton signals are non-linear and non-exponential in character. The correct procedure can be devised only after knowing the mechanism of biophoton emission; one resorts to some arbitrary procedure without its knowledge. An obvious parameter for measuring the strength is the average number of photons detected in an interval at a definite time after stimulation. This parameter has been extensively used but it does not give a unique measure. It depends upon the duration of interval and its position. Different choices of duration and position give measures with different efficacies. The observed dependence on temperature of the strength in a few representative measures is plotted in Figs 2 and 3. The strength has a non-trivial dependence on temperature in all measures. Fig. 2 depicts the dependence of strength in four measures that differ in duration. The durations of these measures were 1, 10, 100 ms, and 1 s and the position was just after stimulation in all measures. The figure brings out the difference in the sensitivity to temperature of signal strength in these measures; the measures based on a smaller duration are more sensitive. The most sensitive measure is the one with 1 ms duration. The figure also shows that the strength in the measure of 1 ms duration fluctuates around the strength in the measure of 10 ms duration. In our view, it is not an intrinsic effect; it is a reflection of the changes in the temperature of sample chamber caused by the regulating unit. The fluctuations indicate that 1 ms measure of strength can sense temperature changes of 0.1°C in a time less than 1 ms. Fig. 3 depicts the temperature dependence of strength in measures that differ in position. The interval for counting photons begins 1, 11, and 111 s after stimulation in these measures. The duration of

![Fig. 2](image)

**Fig. 2**—Temperature dependence of the strength of a stimulated biophoton signal. The strength of a biophoton signal in counts/ms is plotted as a function of temperature in °C. The strength is determined by the average counts in four durations 1 ms (○), 10 ms (□), 100 ms (●), and 1 s (▲) just after stimulation with white light.

![Fig. 3](image)

**Fig. 3**—Temperature dependence of a biophoton signal for different amounts of delay after stimulation: The strength of a biophoton signal in counts/ms is plotted as a function of temperature in °C for the delay time 1 s (○), 11 s (□), and 111 s (▲) after stimulation with white light. The strength is determined by the average counts in the interval of 10 s in the first case with delay time of 1 s and in the interval of 100 s in other two cases. The data points with delay time of 10 m are overlapping with those obtained with delay time 111 s and hence are not shown for clarity of presentation.
The strength of decaying portion decreases from 10 to 20 °C, then increases slowly up to 30 °C and decreases sharply afterwards. In contrast, the strength of non-decaying portion increases slowly up to 22 °C and then decreases slowly. The decaying portion is much more sensitive to temperature than the non-decaying portion. The qualitatively different temperature dependences of the two portions of a photon signal are difficult to explain in any local framework. There has to be a holistic explanation of the temperature dependence of biophoton signal. It again implies that biophoton emission is a holistic phenomenon that is associated with a measurable property in the form of a photon signal. It is conceivable that parameters of the signal could provide measures of some other holistic properties hitherto considered qualitative e.g. strength of the non-decaying portion may measure physiological robustness which attains a peak value in our sample at 22 °C and strength of the decaying portion may measure the response of the system to light stimulation. The sample seems to respond weakly in a robust state and intensely in less robust states occurring at higher and lower temperatures. The drop in the strength after 32 °C can similarly be thought as an indication of the permanent damage to the vitality of the sample caused by high temperature. This is a speculative scenario but its need indicates a strong linkage between biophoton emission and metabolic activities.

Effect of monochromatic stimulation on the strengths of a biophoton signal and its spectral components—These experiments were performed on three samples in PMS3. The results of only one sample have been presented as other two samples gave similar results. The temperature was 25 °C and the dwell time was 50 ms in these measurements. The sample was stimulated by monochromatic radiation of wavelength varying in the range 400-700 nm in steps of 10 nm. The same procedure was used with blue, green and red filters. The counts in the first 50 ms were used as a measure of strength. The measured values of strength at various stimulating wavelengths are depicted in Fig. 4, which has two scales- the scale at the right Y-axis is for depicting the strength of signals obtained with the blue and green filters and the scale at the left Y-axis is for depicting the strength of unfiltered signals and of signals obtained with red filter. The blue and green filters reduce the strength of a signal to less than 10% of its value while the red filter reduces it to only 50-60% of its value. The curve giving the dependence of strength on stimulating wavelength is called excitation curve. All four excitation curves in the figure show structure with four broad maxima. There is also a spurious maximum at around 420 nm in the excitation curve of green filter; it occurs even without a sample. It probably arises from the weak stimulated emission of cuvette by light at 420 nm. It should be ignored. The excitation curve with green filter after the removal of the spurious maximum becomes similar in shape to other excitation curves. A few remaining differences are attributable to fluctuations and so are a few narrow maxima. This is an interesting feature. It implies that the relative distribution of different spectral component does not depend on the wavelength of stimulation. In particular, the stimulation by red light produces a blue component of normal strength. Perhaps, light stimulation and biophoton emission are two different holistic processes. The figure further shows a sharp drop in the strength of biophoton signal at both red and blue end of stimulation, which implies that visible light is more effective in stimulating lichen samples. It has been observed in many living systems

![Fig. 4 — Effect of wavelength of stimulation on the strength of a biophoton signal and its spectral components. Observed counts in 50 ms of a biophoton signal passing through blue (O), green (△), red (△) and no filter (●) are plotted as a function of the wavelength of stimulation. The scale for points obtained with blue and green filters is the right Y-axis.](image-url)
The decaying portion for 12.8 s was determined by detecting photons in 256 successive bins of 50 ms duration in all above signals. The shape of the decaying portion is only marginally different in three spectral components but the nature of decay is non-exponential in all cases. The shape in the decay of any spectral component does not show any appreciable dependence on the wavelength of stimulation. It is based on the appearance of the curve and not on any measurable parameter of the shape. Fig. 5 gives the decay curves of the signal and its three spectral components emitted from white light stimulation. Every fifth point is plotted in Fig. 5 for the sake of clarity. The decay curves with monochromatic stimulation have similar shapes. A puzzling aspect of Fig. 5 is the large strength of red component. The strength is nearly 90% of the signal. It is not comparable to the strength between 40 to 60% obtained in similar experiment with monochromatic stimulation. The curves show pronounced fluctuations when the observed counts in a bin attain a value around 10. These fluctuations cannot be attributed to background, which was negligible and was around one count in 50 ms. The observation of similar non-exponential shape in spectral components suggests a common holistic mechanism in the emission of different spectral components.

We did not get repeatable results with good statistics in similar experiments with interference filters in PMS1. The signal after passing through an interference filter became very weak and showed large fluctuations, the results were similar in bins of larger size. The standard deviation in these measurements was higher than the mean. The large fluctuations forbid quantitative conclusions and the following results should be considered qualitative and indicative. These are based on measurements with bin size of 20s, which is too large for the study of the decaying portion. These measurements were made without stimulating the sample i.e. on a spontaneous biophoton signal. The interference filters 1227, 0, 1246, 6, 1278, 9 (The letter I indicates interference filter and numeric digits give the peak wavelength in nm that is transmitted through the filter with a half width of transmission of nearly 20nm) gave nearly zero strength signal, which implies a negligible UV component. The filters 1422, 1496, 1550, 1595, 1652, and 1695 reduced the strength of the signal to a value less than 10%, which implies a broad spectral distribution from 400-700 nm. The filters 1753 and 1850 reduced the strength of the signal to less than 5%, which implies much smaller IR component. The reduction in strength by long pass filters was dependent on the allowed visible range. The filter WG320 did not reduce the strength of the signal, while RG715 reduced it to nearly zero. (The last three digits in the name of a long pass filter indicate the cut off wavelength in nm). The reductions in GG375, GG495, RG610, and RG665 were in between the above two filters. The results with band pass filters were similar to the ones presented earlier in this subsection.

**Photo count statistics of spontaneous biophoton signal**—We also investigated the statistical properties of a spontaneous biophoton signal in PMS1. For this measurement, a sample was first kept in the dark sample chamber for 10,000s (nearly 3 hr) in order to eliminate the contribution of the decaying part. Subsequently, seven sets of measurements were made with dwell time (or size of a bin)=50, 100, 200, 300, 400, 500, and 700 ms. Each set contained 30000 data points and it took nearly 19 hr to complete the measurements of all sets. In the first step of statistical analysis, various moments of observed counts were calculated for each set. The first three moments namely mean, variance, and skewness are plotted for different dwell times in Fig. 6. The mean increases linearly with dwell time, which indicates that the strength of the signal and background remain constant for 19 hr. Variance is higher than the mean for all sizes of a bin, which implies that the distribution is not normal. Skewness is not zero, which implies a skewed distribution of data points. The fourth moment kurtosis and other higher moments are non-zero and large, which again rules out normal distribution of data points. The statistical
moments indicate that the photo count statistics of the non-decaying portion of biophoton signal is not normal. This has been observed in the spontaneous biophoton signals of other systems as well.

In the next step we evaluated the probabilities of detecting different number of photons in each set. A large number of data points in the set ensured a rather an accurate determination of probabilities. The sets with different sizes of a bin gave the dependence of different probabilities on signal strength. We have used these probabilities for finding the nature of biophoton radiation. The decaying shape of the signal and observation of variance larger than mean indicates that biophoton signal is in a squeezed state. We, therefore, tried to determine the possible squeezed state having probabilities nearly similar to the observed ones. A squeezed state \( |\alpha, \xi\rangle \) is specified by two complex parameters \( \alpha \) and \( \xi \) giving respectively the amount of displacement and squeezing. These parameters are re-expressed in terms of four real parameters \( |\alpha|, r, \varphi, \theta \) as \( \alpha = |\alpha| \exp(i\varphi) \) and \( \xi = r \exp(i\theta) \). The intensity of the signal in the squeezed state is given by

\[
\langle n \rangle = \sinh^2 r + |\alpha|^2,
\]

and the probability \( P(n) \) of detecting of \( n \) photons by

\[
P(n) = \left| \langle n | \alpha, \xi \rangle \right|^2
\]

with

\[
\langle n | \alpha, \xi \rangle = \frac{1}{\sqrt{n! \cosh r}} \left[ \frac{1}{2} \exp(i\theta) \tanh r \right]^{n/2} \exp \left[ -\frac{1}{2} \left( |\alpha|^2 + \alpha^* \exp(i\theta) \tanh r \right) \right]
\]

where \( H_n \) is the Hermite polynomial of degree \( n \). These expressions are valid for radiation in a single mode and their use in biophoton signal implies that various probabilities have the same value in all modes. The expression for intensity fixes the value of \( |\alpha| \). The remaining three parameters \( r, \theta, \varphi \) are obtained by minimising the difference between observed and theoretical probabilities. The values of these parameters for different bin sizes are given in Fig. 7. The minimization programme gave the same values to these parameters for different sizes of bin. The bin size changes the intensity of the signal and the magnitude of displacement but leaves phase \( \varphi \) of displacement and squeezing parameter \( \xi \) unaltered.

Discussion

The above noted features of biophoton signals are difficult to comprehend and seem mysterious. These features rule out the emission of biophotons from isolated and localized molecules or reactions; a signal with non-exponential decay character has to emanate from a holistic mechanism. Both decaying and non-decaying parts do not have exponential decay character. The observed shapes of different spectral components of a signal are similar, if not identical, to the original shape of the signal, which implies that the non-exponential character is not a fortuitous effect and different spectral components require holistic

![Fig. 6](image_url)

Fig. 6 — Statistical attributes of a spontaneous biophoton signal. The mean \( \langle \rangle \), variance \( \langle (\rangle \rangle \) and skewness \( \langle \rangle \) are plotted for different sizes of the measuring bin. The number of data points in each size of the bin is 30,000. The data were taken after keeping the sample in the dark chamber for 10,000 s.

![Fig. 7](image_url)

Fig. 7 — Parameters of squeezed state having the same probability distribution as in a spontaneous biophoton signal: The parameters \( r, \varphi = \varphi(\xi) \), and \( \varphi = \varphi(\xi) \) of a squeezed state of light \( \alpha \), \( \theta \), \( \varphi \), \( \varphi \) are plotted for different sizes of the measuring bin. The parameters are obtained by minimising the square of difference between observed and theoretical probabilities in a biophoton signal whose statistical attributes are given in Fig. 6. \( r, \varphi = \varphi(\xi) \) are dimensionless while \( \theta \) and \( \varphi = \varphi(\xi) \) are in radian.
A common holistic mechanism seems responsible for the emission of various spectral components and perhaps for the emission of individual modes as well. This conclusion does not yet have the solid support of experiment data and may appear as an assumption, but the similar shapes of decay curves of the signal and its three broad spectral components are prime motivations for this assumption. The assumption permits us to compare the observed data with theoretical predictions for single mode radiation field without worrying for the spectral profile. A single mode radiation field can exist in the classical state or in any one of the many possible quantum states. These states evolve differently in time. The classical state is an equilibrium state, so that its intensity should not change with time. Any observed decay in its intensity has to be attributed to the depletion of its emitters with time, which gives exponential decay. A quantum state of radiation evolves and different quantum states evolve differently. The intensity of the signal may change due to its dynamic evolution and it may appear as decay. Many squeezed states evolve in a manner that produces a shape similar to a biophoton signal. This is a novel feature of squeezed state and is the basis for proposing the possibility of squeezed state description of biophoton signals. The proposal needs additional experimental evidence and a mechanism for generation and sustenance of the squeezed state. Photo count statistics provides some evidence. It is encouraging that data at different bin sizes select the same parameters of a squeezed state. The mechanism for generating the squeezed state is not known. It is described by a phenomenological interaction in the model of Bajpai et al.\(^7\). The interaction is a means of incorporating the effect of holistic mechanism operating in living systems. The study of the shape and statistical properties of biophoton signals and their dependence on various physiological and environmental factors may provide some information about the mechanism. The explanation of the shape of excitation curve and spectral profile of emitted radiation need a model of interaction based on the coupling between participating modes. Such a model does not exist and the data is too poor for a phenomenological model. So is the case with temperature dependence of signal strength. The observed temperature dependence rules out an equilibrium description, it has structures and a broad peak between 10\(^\circ\)-25\(^\circ\)C, which is the temperature range of its natural habitat. It again points out some linkage between strength of a biophoton signal and the metabolic activities.

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References