List of publications in referred journals/communicated


5. U. Sharma, A. Goswami and A. Gohain Barua, Coherence of the light of the firefly, *communicated to a journal*. 
Conference attended/participated


3. 9th biannual conference of the Physics Academy of North East (PANE), Dec 18-20, 2014, North Eastern Regional Institute of Science and Technology, Nirjuli, Arunachal Pradesh.


5. National Seminar in Electronics Sciences, Nov 4-6, 2016, Gauhati University.

6. 10th biannual conference of the Physics Academy of North East (PANE), Dec 12-14, 2016, St. Anthony college, Shillong

7. Pre-PhD course work.
Sharp intense line in the bioluminescence emission of the firefly

A. Gohain Barua, U. Sharma, M. Phukan & S. Hazarika

Journal of Biological Physics

ISSN 0092-0606
Volume 40
Number 3

DOI 10.1007/s10867-014-9346-z
Diffraction of the light of the firefly by a grating

Upamanyu Sharma, Mridusmita Phukan, Mana Mohan Rabha, and Anurup Gohain Barua*
Department of Physics, Gauhati University, Guwahati-781 014, India

A control experiment is performed to study diffraction of the light from three species of fireflies: one Indian species Luciola praeusta and two Japanese species Luciola cruciata and Luciola lateralis. The firefly emits stable, continuous light a few minutes after it is made to inhale vapors of ethyl acetate. The diffraction pattern produced by a plane diffraction grating of this light shows that the central principal maximum is predominantly yellow. From the first order principal maximum onwards, green and red colored bands appear. With increasing orders, these bands become broader which appear to suppress the yellow band. This result suggests that the intense yellow region, as a matter of fact, is very narrow, and the firefly most probably emits coherent yellow-colored light.© Anita Publications. All rights reserved.

1 Introduction

The process by which living organisms, such as fireflies, convert chemical energy to light is called bioluminescence. The enzyme luciferase catalyzes the reaction, which uses luciferin, O₂, ATP and Mg²⁺ to yield an electronically excited oxyluciferin species. Visible light is emitted as the oxyluciferin decays to the ground state. This reaction taking place in the lantern of the firefly is called chemiluminescence reaction. While most of the light-producing chemical reactions are only about 1% efficient, this particular one is well-known for its extremely high quantum yield value [1-3]. That is where the importance of bioluminescence lies.

Fireflies belong to the glow-worm family Lampyridae of which there are more than two thousand species throughout the world, especially in the tropics. It is hypothesized that different species of fireflies emit in different wavelength regions because of slight differences in their enzyme structures. Specimens used for our investigation belong to Indian species Luciola praeusta (Fig 1(A)), and Japanese ones Luciola cruciata and Luciola lateralis (Figs 2(A) and 2(B), respectively). Flashing patterns of these three species of fireflies in control and under a strong static magnetic field are documented recently [4]. It is reported that fireflies of the Indian species Luciola praeusta Kiesenwetter 1874 (Coleoptera : Lampyridae: Luciolinae) emit in the peak wavelength 562 nm (greenish yellow) and FWHM (full width at half maximum) 55 nm, extending from 537 nm to 592 nm (green and yellow) [5]. In the same report, it is shown that fireflies of this species emit pulses, displaying resemblance to the output of a multimode laser, of duration approximately 2 microseconds, and about 30,000 pulses constitute a flash of duration approximately 100 milliseconds. For various species of fireflies, measurements on durations of a single flash yield values varying from about 70 milliseconds to a few hundred milliseconds [6-10]. It is shown that the pulses produced by the firefly are manifestations of an oscillating chemical reaction, like the B-Z reaction, and that the continuous train of triangular pulses exhibits both pulse amplitude modulation (PAM) as well as pulse width modulation (PWM) [11-12]. Emission spectra recorded on color films reveal three colors: green, yellow and red, of which the red is not observable to the naked eye under usual conditions [13]. Some of the aspects of firefly flashing studied in recent times are: influences by calcium, nitric oxide vapors, gating of oxygen to light-emitting cells, geographic locations, temperature variations, and static and pulsed magnetic fields [14-19]. Very recently, a narrow strong laser-like line is found in the emission spectrum of the species Luciola praeusta, whose similarity with the random laser is hypothesized [20].

In this work, diffraction patterns of three different species of fireflies are obtained by using a diffraction grating. The predominantly yellow-colored region in the central principal diffraction maximum shrinks down considerably in first and second orders, which raises curiosity. This observation points towards coherence in the yellow sector of the light of fireflies.

*Corresponding author:
e-mail: agohainbarua@yahoo.com; phone: 91-9957257821 (Anurup Gohain Barua)
In vivo bioluminescence emissions of the firefly *Luciola praeusta* at low temperatures

Upamanyu Sharma, Angana Goswami, Mana Mohan Rabha, Anurup Gohain Barua *

Department of Physics, Gauhati University, Guwahati 781014, India

**Abstract**

Dependences of light emission from fireflies on external factors like temperature and magnetic field have been studied in recent times. Interesting conclusions have been drawn and hypotheses put forward in those studies. Here we report steady-state and time-resolved emissions of the Indian species of the firefly *Luciola praeusta* Kleisenweiter 1874 (Coleoptera: Lampyridae: Lyciniidae) at temperatures below 20 °C. Intensity profiles of emission spectra remain the same as those recorded at normal or high temperatures. Two-flash combinations are frequently formed, giving the appearance of the resolution of a simple flash into two. Simple flashes also become abnormally broad with no uniformity in the increase of their durations. The flashes obtained from fireflies at low temperatures are compared and contrasted with the ones under a strong static magnetic field.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Fireflies produce light through a chemiluminescence reaction that occurs within the photocytes of the lower abdominal lantern. This reaction involves luciferin, which is a substrate, luciferase, an enzyme, ATP, Mg²⁺, and oxygen. Luciferase converts firefly D-luciferin into the corresponding enzyme-bound luciferyl adenylyl phosphate followed by recruitment of luciferase amino acid residues to promote the addition of O₂ to luciferin, which is then transferred to an electronic excited state oxyxyluciferin molecule and CO₂. Finally, with the rapid loss of energy of the oxyxyluciferin molecule via a fluorescence pathway, visible light is generated that shines through the skeleton of the abdomen. Since very little heat is given off of this light, this ‘cold light’ has a high efficiency rating — that is where the importance of bioluminescence lies.

Steady-state emission spectra of different species of fireflies have been recorded for over a century. Though existence of distinct groups of bands have been reported for a few species of fireflies [1–3], the generally accepted characteristic of firefly spectra is that it is an intensity envelope with a singular peak and is asymmetric by extending to longer wavelengths. It is hypothesized that different species emit in slightly different spectral regions owing to slightly different enzyme structures [4]. Investigating the structural basis for the spectral difference in luciferase bioluminescence, it is indicated that the degree of molecular rigidity of the excited state of oxyxyluciferin, which is controlled by a transient movement of helix of the luciferase, determines the color of bioluminescence [5].

* Corresponding author.
E-mail addresses: gcohenbarua@yahoo.com (A.G. Barua).

[http://dx.doi.org/10.1016/j.photobiol.2016.01.010](http://dx.doi.org/10.1016/j.photobiol.2016.01.010)
Temperature dependence of the flash duration of the firefly *Luciola praeusta*

Upamanyu Sharma, Angana Goswami, Mridusmita Phukan, Subhachandra Rajbongshi and Anurup Gohain Barua

Firefly flashing has attracted the attention of both poets and scientists for over a century. Here we study the effect of temperature on the flash duration of the Indian species of the firefly *Luciola praeusta* Kiesenwetter 1874 (Coleoptera: Lampyridae: Luciolinae). Recording in vivo time-resolved spectra of specimens of this species of firefly over the temperature range 20 °C–40 °C, it is observed that the flash duration changes with the change in temperature, and the change is substantially linear. This finding implies that the speed of the enzyme-catalysed chemiluminescence reaction, which produces the light of the firefly, varies linearly with temperature.

1 Introduction

Bioluminescence is an interesting natural phenomenon in which living organisms such as fireflies produce light through a multi-step process. An enzyme called luciferase catalyses the oxidation of an organic substrate, a luciferin, using ATP and Mg²⁺. Visible light is emitted during the decay of excited luciferin to its ground state. This photo-emitter system is well-known for its extremely high quantum yield value.¹ ³

A number of studies have been done on the flashing of fireflies to date. It has been concluded that the flash of the adult firefly is controlled by the gating of oxygen to the photocytes, and it was demonstrated that this control mechanism is likely to act by modulating the levels of fluid in the tracheoles supplying photocytes, providing a variable barrier to oxygen diffusion.⁴ Nitric oxide (NO), a ubiquitous signalling molecule, has been found to play a fundamental and novel role in controlling firefly flashing; it has been proposed that the role of NO is to transiently inhibit mitochondrial respiration in photocytes and thereby increase O₂ levels in the peroxisomes.⁵ The firefly flashes are believed to be shaped by neural signals generated in the brain that eventually impinge on the lantern tissue. By simply adjusting the frequency and duration of the stimulus activating the lantern nerves, as per a hypothesis, it is possible to shape any kind of flash.⁶ It is widely believed that octopamine is the neurotransmitter responsible for the induction of luminescence in the light-producing organ of the firefly. It is found in adult lanterns⁷ ⁸ as well as in larval lanterns, lantern ganglia and photomotor neuron somata.⁹

Measurements on a single flash have shown that the duration varies from around 70 ms¹⁰ to a few hundred milliseconds¹¹ ¹⁵ up to a couple of seconds.¹⁶ Recently, time-resolved bioluminescence measurements have been performed for fireflies placed in pulsed and static magnetic fields, which prompt speculations that the magnetically induced current inside the firefly in the pulsed magnetic field affected its nervous system or the photochemical processes in the light producing organ,¹⁷ while the diamagnetic torque and Lorentz forces induced by the 10 T field had inhibitory and stimulating effects, respectively, on the bioluminescence system.¹⁶ ¹⁸

Regarding the effects of temperature on the bioluminescence of fireflies, Lloyd observed, in four *Luciola* species of fireflies from Melanesia, that flash periods decreased with an increase in temperature.¹² Similarly, investigations on the inter-flash intervals of *Luciola cruciata* at five different sites in central Japan indicated a significant negative correlation between ambient temperatures and inter-flash intervals at each of the five sites.¹⁹ In a very recent study of *in vitro* bioluminescence of the North American firefly *Photinus pyralis*, it is found that the intensity of the green component, the only temperature-sensitive quantity, decreases with an increase in temperature, while the lifetime is shorter at pH 7.0 than at pH 8.0, increasing sharply above 30 °C at pH 8.0.²⁰

It is well-known that the rate of an enzyme-catalysed reaction increases as the temperature is raised. An understanding of the effects of temperature on enzymes is important from the point of view of investigations of normal cellular functions as well as of the ability to manipulate these functions through enzyme and metabolic engineering. It is also important from