Compact Light Sources for Biological Applications

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NSF EEC-175579

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Abstract and Introduction:

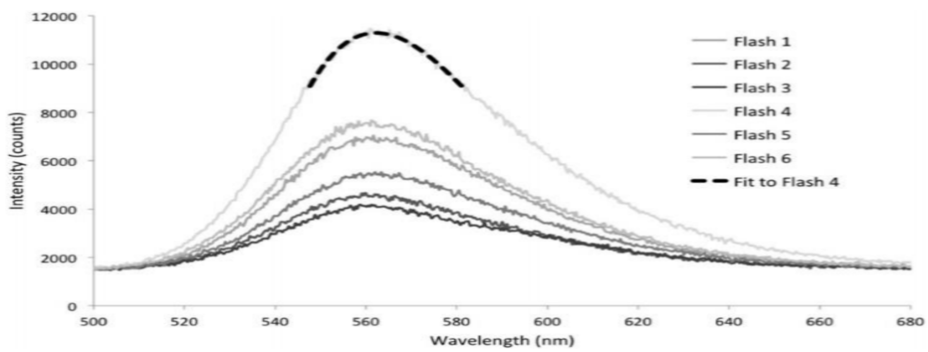
Today's compact light sources are being studied for their use in optimizing plant growth and the study of bioluminescence. Diving deeper into the study of bioluminescence, we have the firefly who produces light through a chemical reaction and then uses that light to attract mates. The chemical Luciferin is responsible for the light produced, and is of special interest to researchers for its possible applications in genetics. Fireflies are hypothesized to be better able to detect a signal with more contrast to the background, and this could explain why some fireflies have a yellow flash, while others have a green flash. This trait could be a product from evolution, and would be considered a way of communicating through signals. Studying the physical attributes of the firefly will allow researchers to connect the dots between phenotype and genotype.

Researchers recorded the emission of hundreds of fireflies, but lacked a way to successfully replicate the firefly's flash. The big problem with replicating the flash of the firefly is creating an emission which wavelength is not normally present in artificial lighting. The device we developed needed to replicate the emission of the firefly and be both tunable and portable for field study. These characteristics are packed inside the LED and are the reason we decided use them to build our device.

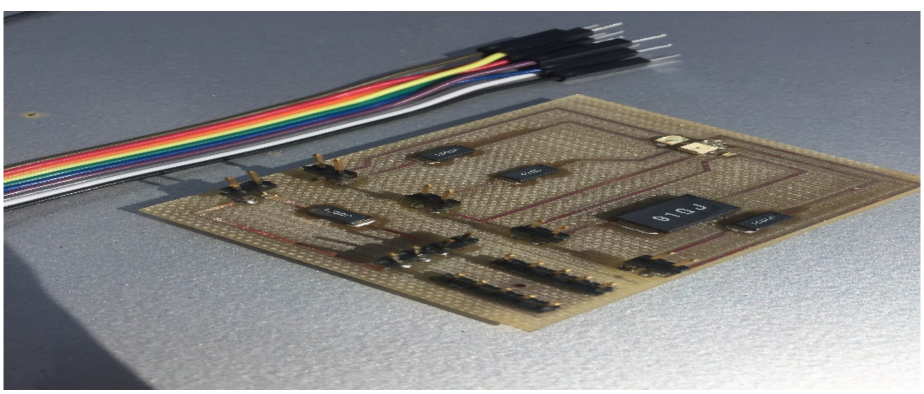
Our device was built with the intent of using light emitting diodes (LEDs) to mimic the firefly. This would allow us to test if a firefly would be attracted to our artificial replication of its flash and does the contrast from the background affect the amount of attraction. This device is a first step in designing a device that can produce any color of light with any pattern in the time and frequency domain.

Methods:

To mimic the firefly, first we decided to use a microcontroller which could output Pulse Width Modulation (PWM). This microcontroller is manufactured by Elegoo and is the Mega 2560 model. PWM allows the microcontroller to output a waveform which mimics the waveform produced by an AC signal and would allow us to give the illusion of analog outputs even though our microcontroller is designed to produce DC outputs. Now with ability to produce the illusion of an analog signal we could effectively make our light emitting diodes fade in or out. This would be especially useful in replicating the fireflies flash because the firefly does not simply produce light and then turn that light off but rather the firefly will produce light in a manner which could be considered fading in and fading out. To confirm we have provided a spectral analysis of multiple fireflies' emission in the figure directly below.



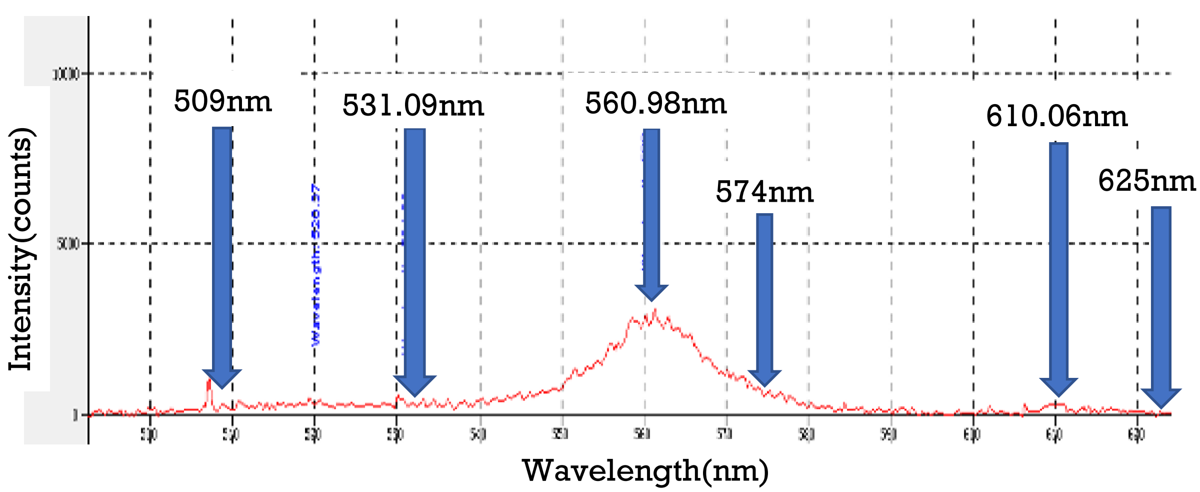
Able to now produce a signal which could fade in and out as the firefly does we needed to create a Printed Circuit Board (PCB). This PCB would be home to our desired LEDs, resistors, and input pins. We used the AutoCAD Eagle program to design our PCB and then exported that design to an in-house CNC milling machine which turned our software rendering into useable hardware. Below is a visual of the completed PCB with the above stated circuitry in place.



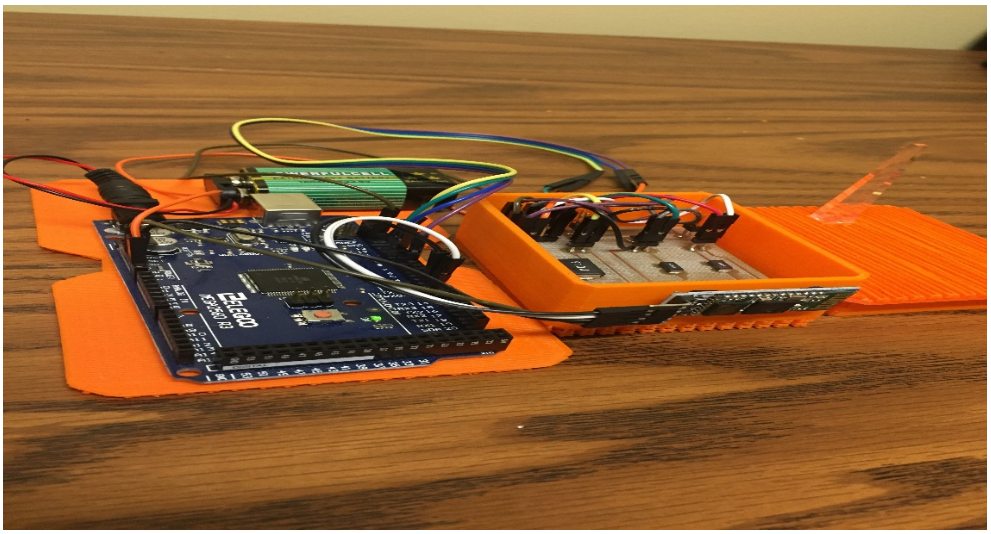
The LEDs on the PCB above were not picked by random and have been uniquely chosen for this project. We needed to produce an emission which wavelength would span 120nm and peak most intensely at 560nm to mimic the firefly. To accomplish this, we used multiple light emitting diodes with variations in peak wavelength and a collimator which combined our multiple inputs beams into a single uniform output beam. We measured the emission of these LEDs individually, while using their respected resistors to not exceed the recommended forward voltage, using the Oceanview 2.0 USB Spectrometer. To perform these measurements, we mounted our fiber optic sensor from the Oceanview Spectrometer and then proceeded to mount our LEDs one by one and record their measurements while the LEDs were in their steady states. The mounts we created allowed us to make consistent measurements which provided us with reliable data. After measuring an abundance of LEDs, we decided to utilize the following: 531.09nm, 560.98nm, 574nm, and 610.06nm. We then collimated the LEDs to begin testing of their emission.

Now testing these multiple LEDs at once we needed to modify our software script which was written in the Arduino IDE. This modification included using more PWM output pins and ensuring that these outputs could also be configured to fade in and out at different times with different intensities. Being that we wanted our most intense peak to occur at 560 we decided to use the max voltage which the microcontroller could produce, while not exceeding the recommended forward voltage, to the 560.98nm LED. We then based the amount of voltage we supplied to the other LEDs around the spectral analysis. Those LEDs which overpowered our desired peak would have their voltage decreased and thereby decrease their intensity, and vice versa to those who did not have enough intensity to produce smooth and continuous output.

Knowing from previous testing that our LEDs wavelength would span approximately 15nm less than peak wavelength and 15nm more than peak wavelength we decided to assign a 29.89nm gap between our lowest wavelength LED (531.09nm) and our peak wavelength LED (560.98nm). This gap allowed for our lowest wavelength LED to start its emission at 509nm and then peak at 531.09nm. After that our 531.09nm LED's emission then was superimposed with our peak wavelength LED (560.98nm). The peak wavelength was then achieved and as the peak began to fall again the 574nm LED superimposed its way on to the 560.98nm LED. This allowed for a more graceful fall which was then accompanied by the emission of the 610.06nm LED who reached its peak and then ended its emission at 625nm. Below are the results of our final spectral analysis.



After obtaining the above spectral analysis we decided to add both a Bluetooth Module (HC-05) for remote control and a portable power source to allow for portability and increased mobility while field testing. The portable battery source was a seamless integration to the microcontroller which required no additional software manipulation. The Bluetooth Module did require additional setup parameters in the Arduino IDE script but functions flawlessly after successful setup. Below is our final device.



Conclusion and Future Applications:

In conclusion we have found that it is indeed possible to mimic the firefly using collimated Light Emitting Diodes (LEDs). This same concept could be applied in making a device that could control all wavelengths in the visible spectrum and will not only allow for testing of previous hypothesis but also those in the coming future. Further applications could include optimizing plant growth and advancing the study of Bioluminescence.

Acknowledgements:

First, I would like to thank Leslie O'Neill for being more than just a coordinator for the Research Experience for Undergraduates (REU) but instead being a friend who we as interns could always turn to. Thank you too Dr. Shen who always provided me with guidance and motivation to do my best. Without the prior research of Kathrin Stanger-Hall of the University of Georgia my research for this Summer would not have been possible therefore I am thankful to her for being a key contributor.
I am very thankful to National Science Foundation (NSF) whom funded this program and I would also like to thank the Institute of Electronics and Nanotechnology (IEN) staff who were always friendly and knowledgeable. Last but not least I am very

grateful to the National Nanotechnology Coordinated Infrastructure (NNCI) for providing us with the tools to succeed as researchers.