

PROPOSAL

HAND HELD TUNABLE LIGHT SOURCE

Sponsor: Electro Optics Laboratory at Michigan State University

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Executive Summary:

Solar cells play an important role in transforming solar energy into electricity through the photovoltaic effect. As such they have become a crucial element in providing clean renewable energy as more consumers turn away from traditional fossil fuels (Bent). The current method of testing solar cells uses a broadband light source and optical grating to change the wavelength of the light to measure the quantum efficiency of solar cells at local spots. The required components for the current method are housed in a system that is costly, cumbersome, and table top in size. Team 13 will create a cheaper, more user friendly testing device composed of LEDs that can be controlled via a laptop computer to provide at least twenty-five peak wavelength points over a spectral range of 400 nm to 1100 nm. During test operation the device will illuminate a local spot on a solar cell of area 1 mm² area with a total power of 0.1W while the solar cell is monitored using a voltmeter to determine light-conversion efficiency. The device was requested for use in the Michigan State University Electro Optics Laboratory to introduce students to the potential of solar cells as alternative energy sources. In addition, we plan to explore the potentials for commercial applications as a cheaper portable alternative to current devices on the market.

Background:

The goal of the Hand Held Tunable Light Source is to provide artificial sunlight in ambient air conditions for highly efficient solar panel testing. The wavelength of light is determined by: $\lambda = \frac{v}{f}$ where in free space (which is where the λ desired would be needed) v is the speed of light or 3×10^8 m/s. Since all of the light will be traveling at roughly the same speed, it is the frequency of the light that changes the wavelength and therefore changes the color the light is perceived to be by the human eye. Team 13's tunable light source will cover the electromagnetic spectrum beyond visible light by changing which LED in our array outputs light (ie. changing the frequency of the light outputted).

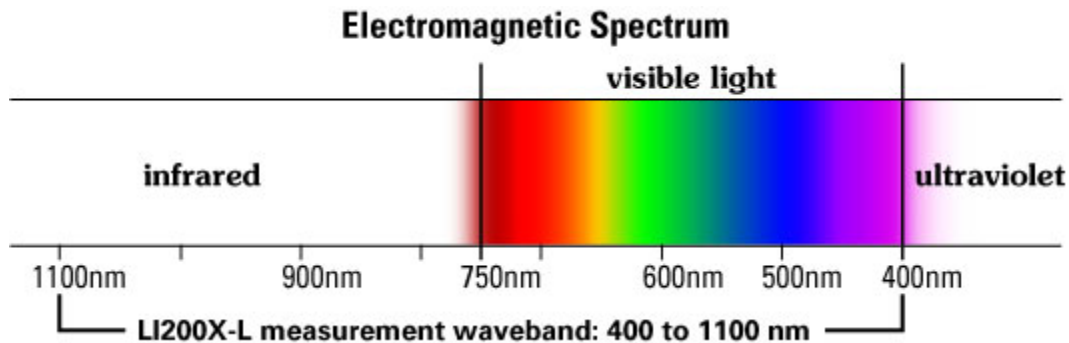


Figure 1. Light Spectrum

LED Concepts:

LEDs is an acronym for light emitting diodes. LEDs are pn junctions that have the usual ability to conduct electrical current in a unidirectional manner. Unlike common diodes, LEDs are fabricated in materials that support radiative transitions and they therefore emit light that can range from ultraviolet to the infrared. LEDs are far more efficient than conventional incandescent light bulbs, and have a longer lifespan. They are commonly used in devices as indicators for notifications indicating that the device has completed a specific task e.g. an LED

on a charging phone, indicating that the phone is charging or has been charged. The advantages of LEDs use over other technologies are limitless.

Semiconductor LEDs produce specific wavelengths of light that are band gap dependent. Therefore an array of LEDs will be used to create twenty-five peak wavelength points that cover the spectral range of 400 nm to 1100 nm.

Lenses Concepts:

The LED spectrum will be redirected and focused nearly to a 1 mm squared via lenses. The light spectrum will be focused using 2 biconvex lenses as shown in Figure 2. The first biconvex lens will be a 6 inch radius lens that will direct the light towards the focal length. The second lens, is a 3mm biconvex lens, will be focused after the focal length in order to obtain a more focused point. The lenses are able to function through the spectral range of 400 nm to 1100 nm.



Figure 2. Biconvex directing light.

The lenses that will be used for testing are uncoated lenses. The lenses will help determine how efficient a biconvex lens can bend light without losing much power. However, for the final project we will be using coated lenses that will reflect less light and refract more light efficiently. Thus, allowing us to get near the desired 0.1 W per 1 mm squared of output power.

The team

Microcontroller Concepts:

Once a spectrum-covering array of LEDs is assembled, a microcontroller will be used to switch them off and on as specified by the user. Since the client wants to control the device from their computer via USB, the microcontroller requires some form of serial communication with an external device. Since this product will also be designed to be portable for in-field use a secondary user interface that doesn't require an external computer will be added. Two interfaces are being considered, one using potentiometers as a turntable knob, or tact switches as buttons to control.

The list of needs we have from our microcontroller are as follows:

- 25 digital output ports, one for each LED (reduced to 5 if additional multiplexers are used)
- Serial communication capability via USB
- 4 analog inputs for potentiometer readings
- 4 digital input ports for tact switch readings.
- PWM output of approximately 1kHz with an acceptable resolution (>100)

Software Concepts:

The Tunable Light Source needs software to control the LEDs color and intensity. Software under consideration includes the following:

- The Arduino integrated development environment (IDE). It is a cross-platform application written in Java (very similar to C program) that allows easy control of IF loops. Most parts in our project will be coded through it.

- Graphical user interface (GUI) is a type of interface that allows users to interact with electronic devices through graphical icons and visual indicators. The GUI will control the Arduino in our project.

Conceptual Design:

Our leading design uses an array of LED's and a series of lenses to condense the emitted light for 0.1W of power on a 1 mm² area. A microcontroller with an optional USB computer interface will be used to select which band of color, as well as tune the intensity of light over the designated area.

LEDs and Lasers have been researched for this project as a light source. Lasers offer an already focused beam, meaning we wouldn't need lenses to focus it onto the 1 mm² area. However, lasers that can provide 100 mW of power are quite expensive, and are difficult to find in all twenty-five wavelengths we need. Furthermore, they require significantly more cumbersome circuitry to drive them, meaning more space as well as more power. LED's are cheap, replaceable, and come in a variety of colors. While they are not focused, they are directional, and therefore easy to focus ourselves using lenses.

A series of lenses will be used to focus the LEDs down to a 1 mm² area. Since lenses have one focal point, moving the output around to test an entire solar panel would be difficult. To solve this problem one end of a short fiber optic cable will be attached to the focal point, allowing the other end to be directed by the user with ease.

To tune the intensity of light, two options have been explored. The first entails using a pulse width modulation (PWM) signal to provide base current to a switching transistor. Since diodes are binary components (either off or on), changing the intensity they output light at can be challenging. Using PWM, one can switch them on and off very quickly and adjust for how long they stay on each cycle. If the switching frequency is high enough, the light appears to be dimmed. This idea is the most promising, since it would only require one extra transistor and a PWM microcontroller pin. However, the relation of light intensity vs. power output of a solar cell is non-linear. This means PWM may not work, as

the light is not actually being dimmed, but switched. The second idea was to use two polarized lenses, with a servo motor to change their angle to each other. As the angle changes, more or less light will be filtered as a function of the angle difference from 0-90° as governed by the following equation:

$$\text{input intensity} \left(\frac{1}{2} - \frac{\text{input angle}}{90} \right) = \text{Output intensity}$$

While this allows us to turn our light intensity as needed without conflicting with the non-linearity of the solar cells, even at 0°, half our light is lost, reducing efficiency dramatically. Due to this loss of efficiency, PWM LED design may prove to have the better set of tradeoffs as research shows that a PWM LED with a frequency of approximately 1 kHz shows negligible differences in the solar panels output. Both PWM LED and polarized lenses are currently under exploration.

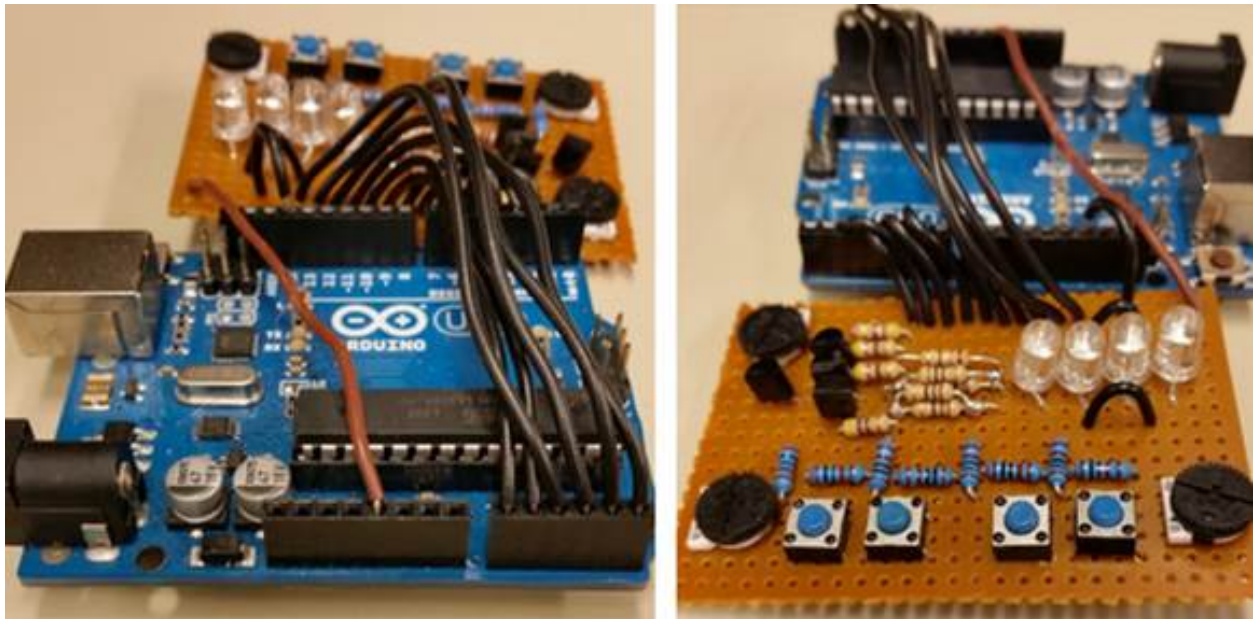


Figure 3. Prototype of proposed design

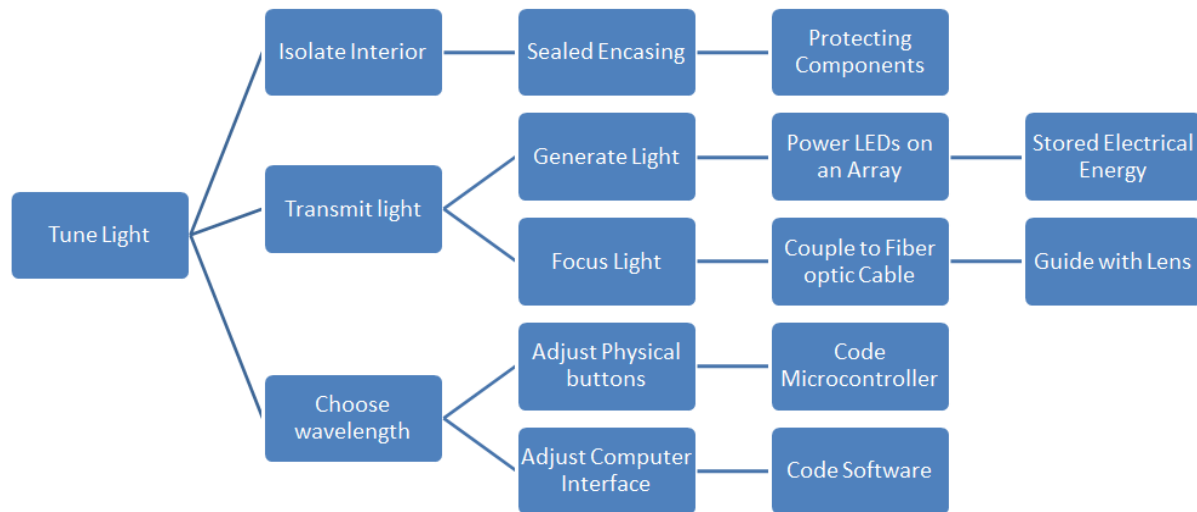
Risk analysis:

A risk assessment of the proposed tunable light source design solution has identified the following points for which careful design and implementation will be required. Firstly, as the device is designed for student use, it is essential that it is user friendly and accurate so that the concept is correctly grasped by the student. A simple two parameter GUI is proposed for implementation, with intuitively obvious graphically-guided selections for wavelength and intensity. A photodetector-based calibration procedure will ensure consistently reproducible results.

Secondly, since the device is designed to be portable for field use, we must consider its physical robustness. To compensate for this, we must ensure the all components are tightly mounted and secure and that the housing unit is durable. An integrated hard foam shock absorbing layer is proposed, along with an integrated vent to simultaneously provide acceptable air-cooling of the interior. Drop tests are planned as part of the overall device assessment, with emphasis on lens and LED mounting security. Furthermore, we must ensure the tunable light source can operate in variable weather conditions (e.g, water resistant, heat tolerant). In order to ensure this we will tightly seal the housing as well as use components that are heat tolerant on a range of -20 F - 115 F, In addition a battery is under consideration that is both water and shock proof.

Finally we have to consider the lasting integrity of our hardware. For example, the potentiometer used for control intensity can wear out over time. Although our initial installation calls for the xxx model with a yyy average lifetime, eventual replacement should be easy and secure. To address this, the housing unit will be able to open for user replacement of certain parts, including the control potentiometer and individual LEDs.

Fast Diagram:



Budget:

Project Management Plan:

Potential for Technology Transfer:

In addition to solar cell testing, the tunable wavelength technology can be applied to a variety of other uses. First, it can be used in Agriculture to encourage greenhouse plant growth since "...it is the red, far-red and ultra-violet light that plants use in the manufacture of carbohydrates" ("Getting on Right Wavelength"). It has been determined that most plants prefer a ratio of 3:1 of red to blue wavelengths for optimal growth, however this ratio can vary from plant to plant as well as during stages of the plants development cycle, this is where the

team 13 Tunable Light Source technology can be utilized to flexibly produce optimal growing conditions (“Getting on Right Wavelength”).

Another area the team 13 Tunable Light Source technology can be applied is in the medical field. One example is in treating Jaundice, a common disease among newborns that manifest itself as a yellowing of the skin and other tissues. In critical cases Jaundice can cause hearing loss, physical abnormalities, brain damage, or death (Thoppil). Most treatments require compact fluorescent light bulbs that are tedious to change, use up too much energy, and can be irritating to newborns. LEDs are under recent explorations as an alternative. “LED lamps can help treat jaundice faster than conventional phototherapy lighting...researchers found that at a certain wavelength the high intensity LED light was the most effective” as well as using “... less electricity than conventional lamps and last(ing) much longer without a bulb replacement”(Thoppil). With the team 13 Tunable Light Source adjustable technology hospitals will be able to set the LEDs to output the optimal wavelengths on a per case basis.

Color Blindness is another medical condition where the team 13 Tunable Light Source technology can help. Those with color blindness cannot see certain wavelengths of the visible spectrum. This disability can be a safety issue those with colorblindness as well as those around them. A person who is color blind cannot perceive green light but both color blind and non-color blind people should be able to perceive “green” from blue and yellow light. By applying this technology to current products, such as stop lights, we can avoid unnecessary accidents.

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