

Testing Design for Sunglass UV Protection

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Abstract

Ultraviolet rays are highly damaging to the eye. Sunglasses are often the only source of protection offered. Unfortunately, many lenses do not appropriately protect from harmful UV radiation. Our design proposal is a machine that will be able to test the effectiveness of any sunglass lens. We use LEDs as a substitute for natural sunlight to emulate UV rays. These rays will be detected by two devices: the sub-pico meter and magnesium zinc-oxide. These detectors can measure the amount of UV rays transmitted through the lens. The processor then uses this number and a calibrated number to calculate a resultant percent of UV protection, which is finally presented on an LCD display. This technical document will explain our research and development of our design plan.

Executive Summary

Problem Statement

Sunglasses have become a fashion statement over the past few decades. Unfortunately, people are unaware of how damaging the sun's rays can be to their eyes when they are wearing poor sunglasses. The standards of UV protection, we think, are too low and not only need to be improved, but also enforced. A testing device that is capable of providing UV light and detecting it would be a great way to improve sunglass consumerism. The problem is being able to provide a light source that can cover the entire ultraviolet light range and beyond, while also having an equal or greater intensity than natural sunlight. We have devised a design that is capable of meeting these requirements, while keeping the procedure simple. Using this ultraviolet testing device will raise the standards as well as provide a way for consumers to know they are buying a quality product

Approach and Key Requirements-Constraints

Our testing device will measure the UV protection provided by any type of sunglass lens. It will use an LED fixture containing 40 single-chip LEDs as a UV ray source. These rays will be directed to the lens on the sunglass and any unblocked rays will continue onto the detector. Our detector will consist of 2 parts: sub-pico meter, and magnesium zinc-oxide. Both detectors will work together as one to be able to have an accurate reading of the UV rays. If the sub-pico meter does not react, the lens is 100% protective. This meter alone will send a message to the microprocessor, confirming full protection. If the sub-pico meter does react, the zinc-oxide detector will then take over and measure the amount of rays that were emitted. This result will be sent to the microprocessor for calculation. Using a programmed calculation and the calibration constant, a percentage of UV protection will be displayed on the LCD screen.

Despite our design plan, there are some technological difficulties to overcome. Although we have decided that LEDs would be the most efficient UV emitting source, they tend to weaken in low wavelengths. Fortunately, LEDs are small and inexpensive which allows us to use multiple diodes in a chip-set. This will increase the strength of these weaker wavelengths. Another drawback to the design is the life expectancy of the magnesium zinc-oxide. Over time it can burn out on its silicon base, needing replacement. Regardless of this inconvenience, this detector's ability to detect into UVC range makes it worth the periodical replacement.

Results Sought

We strive to have our product working within 3% accuracy upon completion. As our product becomes sought after in the market, we can use the revenue to improve the design and increase its accuracy. We also aim to increase the calibration interval to over one month. Another desired improvement is to lengthen the lifespan of the magnesium zinc-oxide detector, which now averages three years, depending on the amount of use the device is put through.

Potential Impact

As stated before, our product will allow users to test their sunglasses to be sure they are buying a quality product. UV rays are a main cause of cataracts and other eye related damages. Our goal is to provide the public with a way of knowing if their eyes are being protected. Our device can help improve the UV standard compliance around the world, which will hopefully lead to better eye care.

Problem Statement

Introduction

A new form of testing is needed so both the seller and consumer have accurate data on how protective various types of sunglasses are. From this test, the information found will show how proficient sunglasses are at protecting the eye from damage due to ultraviolet radiation. Testing devices already exist; however, they are not always easily accessible to everyone. Our goal is to produce a machine that is not only affordable but also fairly portable. Obviously, the economy today is looking to spend less on the essentials, so affordability is key. Also, portability

will be necessary, not only for shipping, but also the consumer will want to be able to move the device easily to wherever suits them best. From these two factors, mass production will increase with revenue, leading to a more quality, dependable product for our client. Then, from our product, our customers are able to provide a quality pair of sunglasses for their consumers, leading to better eye care.

UV testing will help the consumer have an easier time choosing a product that is efficient in blocking ultraviolet rays. Today, a majority of the people that wear sunglasses do so to look good. However, wearing cheap sunglasses may be detrimental to your eyes due to extensive pupil dilation. Sunglasses block light from getting to your eyes, causing your pupils to dilate, letting more light in. If the sunglasses being worn are not blocking enough ultraviolet light, the eye is being damaged. It would be better to just not wear sunglasses at all. With this test, consumers will be able to buy a quality product at an affordable price, while being stylish at the same time.

Historical Introduction

Originally, sunglasses were used to conceal eye expression in court. Since then, sunglasses have adapted to fit the current need of eye protection. In the eighteenth century, an apprentice optician named James Ayscough, used a blue-green tinted glass to possibly improve specific eye impairments. However, he had no intention in protecting the eyes from damaging rays. In 1920, UV light was finally discovered to have hazardous effects on the eye. Unfortunately, society did not believe it would have an extreme detrimental effect. Sam Foster was the first to introduce sunglasses to America. He found a ready market on the shores of Atlantic City, NJ. This was the beginning of the Foster Grant sunglass company. From this market, sunglasses as a product started to become well-known, giving other people ideas on how to use them. In 1936, sunglasses became polarized to reduce glare for pilots while flying. This was done by using an Edwin H. Land Polaroid filter. It was not until 1960 when a clever advertisement from Foster Grant launched sunglasses into the fashion world. (Ament) From here, companies such as Oakley, Ray-Ban, and Maui Jim have become successful in selling a fashionable product in the economy.

Carbon arc lamps are a dangerous source of ultraviolet rays; however they were used for lighting in theatres. When used, they caused fading and degradation to the curtain as well as damaging the sight of the actors. Not until this point did testing begin. "The original UV testing

machines typically involved a centrally placed carbon arc with a large rotating sample drum with the samples placed on the inside of the drum. The equipment was typically very large and the light spectrum was very intense. However, it served as a useful method for screening suitable materials for use in the theatre environments. As the test was developed further, the light source was filtered to more closely simulate outdoor exposure but even the filtered light is a poor simulation of the sunlight spectrum. Although these lamps are dangerous they are still used in spotlights and some standards call for this type of testing.

The basics of ultraviolet testing are simple. Overall, what is needed is a source, a detector, and a test specimen; in this case, a pair of sunglasses. Unfortunately, it is basically impossible to duplicate the exact intensity and variety of rays that are created by the sun. However, we do know what rays are harmful to the human eye and from that we can test these rays at multiple intensities. The intensity of a ray is measured by the crest and trough (maximum and minimum) of the sinusoidal curve. From this range, we can see what rays and how much of those rays are blocked by the sunglasses

When searching for a capable source of ultraviolet light, we are going to need a device that is able to reach high intensities, similar to the sun. Also, this source must have a large range of wavelengths, covering the entire UV range. Light Emitting Diodes (LEDs) are a small, inexpensive light source that is capable of being plugged in to a simple light fixture. These bulbs can reach high intensities when bunched together with several other bulbs. Additionally, they have a wide range of wavelengths, covering the ultraviolet range and more. These features make LEDs a perfect source candidate for our testing device.

Now that a source is available, a detector would be needed. This may be more difficult to find because specific sensors are only capable of reading a small range of rays. Two separate sensors may be needed to detect all ranges of wavelengths. Some detectors are capable of detecting a specific range of wavelengths. Fortunately, this range covers most of the UV range that we need to be detected. Imego Mfg. is a company that produces this type of product. Sunitive is an extremely simple, small detector that is able to sense wavelengths ranging from 280nm to 400nm.^[9] Although this does not include the entire span of wavelengths, it does cover the majority of it. It is small and compact, which makes it easy to move to a desirable position, relative to the source. The positioning of this device is key so the entire source of light can be easily detected. Any shifting or inaccurate positioning can alter our results.

With the source and detector in place, the sunglasses can just simply be put into a box with a stand inside. This box will block all outside light from skewing the results. However, before the sunglasses are mounted into position, a calibration must be done. The testing device is turned and the LEDs direct light straight into the detectors. The detectors send this maximum value to the microprocessor which will then have the screen display the result, which will be 0%. We set this as our calibrated amount of light and use this to run the test. Once the sunglasses are put in place, the test can begin. The rays hit the sunglasses and the detector reads how much of that light transmits through. The microprocessor computes some simple algebra and sends a percentage of UV protection to the display. From this simple procedure, companies and sunglass vendors can sell a quality product and know exactly what their product is capable of.

The Market and Competitive Product Analysis

Our product will be able to be sold to numerous areas in the sunglass business. Although the primary target is retailers, who would use the product to confirm to their customers they have quality items, there is another side to the marketing. Opticians need to ensure their patient's safety and make sure the glasses they give them are beneficial. Having a UV detector in their office or store would benefit their practice and their reputation. Also, sunglass producing companies would buy this product so they can test new products, as well as the effectiveness of their old ones, and make adjustments where necessary.

Implications of Project Success

Once our product becomes a staple in the sunglass industry, many benefits will happen. Firstly, customers can be sure that what they are purchasing is a quality item, and more importantly, is good for the health of their eyes. This means that companies that make profit from faulty products will see their sales fall and allow honest companies to get the sales they deserve. In addition, any companies mislabeling products can be put on trial for fraud. This product is the next evolutionary step in the sunglass industry that has been around for over seven hundred years.

Design Approach

Introduction

In today's world, people in society care about their personal health. The UV radiation from the sun causes multiple optical injuries that can lead to blindness. Our product will allow consumers to be sure they are buying quality sunglasses that will protect their eyes. What is needed is a source of UV light, a mounting container to block out ambient light for the sunglasses, a UV detector, a math chip, and display for results. Choosing the correct grouping of parts for the design is pivotal in creating a quality product for the consumer. Because UV light spans across a wide range of wavelengths, various sources and detectors must be considered for this design.

Solution Space

UV Light Sources

Lasers

Choosing a UV light source is the start of the design process. There are four main types of UV emitters to select from. First on the list are lasers. Lasers excel in producing an extremely precise wavelength of ultraviolet light. Although a laser can only emit one wavelength at a single point in time, they can be tuned across a range of wavelengths. This will allow for a more accurate result from testing. Since lasers emit a beam instead of a cone of light, the laser would have to be pointed directly at the sensor to get a reading. Any misdirection could cause skewed results. In addition, lasers emit heat at the sensor which can also throw off the outcome of the test. Finally, this source can be rather expensive for the consumer.

LEDs

The next candidates for UV deliverance are LED lights. These can reach a wide range of wavelengths while also using a significantly low energy amount. LEDs are inexpensive, reliable and generally have a long life span. Their down side is they emit an inferior intensity compared to lasers. They are sensitive to the amount of power supplied to them, possibly resulting in burnouts. Lastly, light emitting diodes are not precise in the direction of the light being emitted. (Woodall)

Arc Lamps

Another choice for a source of UV light is arc lamps. Although they produce a wide range of wavelengths, filters can be used to narrow down this range. These lamps are rather powerful and resemble natural sunlight accurately. Downsides include heat irradiance and imprecision. They also require a high input current. When turning on an arc lamp, they need a few minutes to heat up and reach the maximum intensity. Also, when turning them off, they require a 5-10 minute cool down before they can be turned on again.(Atlas)

Incandescent and Fluorescent Lamps

The final contender for an ultraviolet source is lamps. Two types of lamps are incandescent and fluorescent black lights. They are safe to use, inexpensive, and have a long life span. However, they do not cover most of the wavelengths we are looking for. The main types of UV wavelengths are UVA, UVB and UVC. The draft International Organization for Standardization (ISO) designates the range of these as follows:

Table : UV Wavelengths

UV Ray	Wavelengths (nm)
UVA	400- 315
UVB	315-280
UVC	280-100

Detection

The detection of our UV light source is another main component of this testing unit. What we need is a detector whose range is just as large as our source. This is a complicated area. There are plenty of options; however all have ranges that are sporadically across the UV wavelengths and beyond. Three types of detectors that are possibilities for this testing process are known as photo-detectors, which can convert light into current or voltage. A photomultiplier multiplies the current of light it absorbs and uses that to detect a very low incident flux of light. Although these are extremely sensitive, they are capable of picking up thermal emissions as well as wider range of wavelengths than what is necessary. Another form of photo-detectors is a photodiode. This detection source basically does the same thing except it uses excited electrons to produce this current. A positive of a photodiode is that they are also extremely sensitive, and can pick up the higher wavelength range. Unfortunately, they are only capable of detecting down to 300nm, which is only half of the UVB range. The last photo recognition source to be considered is a phototransistor. These are almost a combination of the previous two, using electrons from the photons to produce a current in the photodiode. This current is then amplified by the transistor's current gain. They do detect a wide range of wavelength (190-1100nm), but have a longer response time when compared to a photodiode. (Globalspec)

Sub-pico Meter

Two basic forms of detection can be considered for our ultraviolet testing unit. One of them is a sub-pico meter. This meter is a scientific device that uses special CCDs that produce a voltage when a wavelength between 10 to 400 nm is detected.(Heras, Subias) This detection source has a range that covers all of what we need. Unfortunately, the only answer is would give is a yes or no answering saying if any amount of ultraviolet light was detected. No percentage value can be obtained from a sub-pico meter. Another simple option is UV sensitive paper. This paper works the same way as ammonia leak paper does. If there is a set of piping that needs to be

checked for leaks of ammonia, a person can use this paper and run it along the pipes. If there is a leak, the paper turns purple. This UV sensitive paper will be tainted in a similar way when it comes in contact with UV wavelengths. Although it is very simple and convenient, they are very prone to be tainted by ambient light while being placed in the testing unit.

Magnesium-zinc Oxide

The last form of detection is a complicated chemical makeup called Magnesium zinc oxide. The way this UV sensitive candidate works is the ultraviolet light is absorbed into the material. Then an electron-hole pair is generated when a photon of energy equal to or higher than the band-gap is absorbed. Absorbed UV and the photo-generated hole contribute to local charge neutrality and free up the photo-generated electron to enhance the conductivity of the device. (Hullavarad) This will produce a specific current or voltage, which is proportional to a wavelength range and intensity. Unfortunately, this material is patented. To use this detection source would require more money to buy the patent for the material from the creator. Another downside is that the silicon base in the chemical make-up is very sensitive and can easily be damaged. However, it does cover most of the UV range and is visual blind. This means that it will not detect the visible spectrum. Whichever detection source we use, most produce a current or voltage. This requires a mathematical computer chip to convert the voltage into a wavelength to tell the user what has been detected.

Computing

If using a detection source like a sub-pico meter, a computer chip is unnecessary because the meter just tells the user immediately whether it detected UV light or not. However, if the testing unit is using any of the other sources, a computer chip with a programmed equation must be used to convert the voltage back into a wavelength, which it was originally detected as. This system is similar to the motherboard of a calculator. On the UV test computer system, there would be a random access memory (RAM), read only memory (ROM), and a central processing unit (CPU). The RAM is what holds the data gained from the system. The results are held on the RAM, however the information stored on here is temporary. Once the testing unit is turned off, the results are no longer available, unless stored on an external memory drive. The ROM is what holds the actual equation and any other data that is always needed when the testing occurs. This

equation is sent to the CPU, which then does the calculations. The microprocessor is the computer chip that does the actual math for the testing process and sends the result to the display.

Display

When all the calculations are finished, the system has to send them somewhere so the user can see the results of the test. The testing unit has two options on displaying the results. A printed hard copy of the results can be used, which would take out the necessity of any screens. The upside of this version is that you have the results in hand and can take them anywhere and show anyone. However, it does require paper and ink. In today's society, it is more efficient to be green and go paperless. This is where the other option comes in. An LCD screen would be the perfect display for our testing unit. Basic forms of screens with low resolutions are available at a low price. They do not require much power and, of course, are paperless.

Power Source

The final decision that must be made to finish off our product is a source of power. Although there are many options that are all capable of giving the right amount of power to the source, detector, CPU, and display, there is only one choice that is necessary. An AC adapter would be perfect for our testing unit. They come in various powers, supplying a range of power to the unit. Depending on the source of UV light, the power that is transmitted must be precise. Not enough power will result in a lack of intensity, giving inaccurate results; too much of power can burn out and destroy some light emitting sources. An AC adapter is the only feasible power source for our design, and this is what we decided to use along with a specific source, two detectors, CPU, and display screen.

Recommended Design Approach

As an ultraviolet light source, we propose that using LEDs would work best and be most cost-effective. These LEDs would shine through a mirrored tube, causing the light to go through the sunglass lens into the detector. We decided to use a combination of UV detectors. A Sub-pico meter will give us a basic yes or no answer. The other one we used was the magnesium zinc oxide material. This would allow us to obtain a percentage result. This result then is sent to CPU to convert the data gained from the chemical material to a simply understandable result. Our CPU then sends this data to an LCD screen where the user can see the final testing data.

We found LEDs to be an appropriate source of UV light. This is because they are inexpensive and quick to light up to maximum intensity. They also do not require a high source of power. Other sources can be expensive, such as lasers. Also, arc lamps not only require a high power input but also take a significant amount of time to heat up to maximum intensity. Additionally, incandescent and fluorescent black lights do not cover much of the UV wavelength range. LEDs were chosen as our source, which will direct their light to the sub-pico meter and the magnesium zinc oxide material. The sub-pico meter is the most basic of all the detectors. It is not overly sensitive and is responsive to the entire UV range. The magnesium zinc oxide would be our more precise detection. Both these detectors are capable of detecting the entire UV range unlike the photo-detectors. Also, they are not as easily damaged like the UV sensitive paper. Our combination of detectors will give us a simple and precise result to the testing.

Once the detection process occurs, the CPU will convert the data and send it to our LCD screen. As I said before, a CPU is the only feasible option for this testing unit. As for the display, we chose a low resolution LCD screen. It eliminates paper from the process and it will show basic results that the user can easily understand. These screens are inexpensive and come in all sizes. We took all factors into account, including overall cost, UV range capability, sensitivity, and convenience. From comparing all possibilities of sources, detectors, mathematical and display options, we came to our design conclusion.

Overview of Recommended Design

There were many options available while choosing which part we would use for the product. Some of the parts would work more efficiently with a certain part, but less efficient when looking at the overall picture. Firstly, we decided LEDs would be the best source for emitting UV light. LEDs can reach wavelengths of 210 nanometers which is midway into the UVC range.(Day) Even though some lights such as the arc lamp can reach the lower end of UVC, we decided a 40% sample of the UVC range would outweigh the drawbacks of using an arc-lamp. This limitation will be clearly printed in the manual as well as on the machine itself next to the LCD display.

The product would house an array of LEDs similar to how traffic lights are designed. These LEDs will vary in wavelength emittance to cover the entire UVA and UVB range, and roughly 40% of the UVC range. As we have previously stated, LEDs produce a weaker light than most of the other solutions especially when approaching the UVC range. To mitigate this

limitation, we decided to use mirrored tubing to guide the light from the LEDs to the lens. If the lens fails to block all rays, a second mirrored tube will lead to the detector as shown below.

Figure

In addition, the sunglass lens will be tightly secured on both sides by a rubber cover on both ends of the mirrored tubing. These ends will be able to be adjusted to fit the lens from both sides simply by turning a knob. This will ensure accurate measurement and incorporate many sizes and types of sunglasses.

Next is the detection method. We decided that using two separate types of detection would both improve efficiency of the readout and reduce maintenance cost. The first test will run with the sub-pico meter as the detector. This will give a pass/fail on the sunglass lens. If the meter does not react, it means the sunglass lens is 100% UV protective and no further testing needs to be done. ^[10] If, however, it fails the test, we decided on using the magnesium zinc oxide method of detection. This method is very efficient in that it is visible-blind, which means even if ambient light makes its way into the test, the results will be unaffected. Also, this detector can sense UV light down to 150nm where other detectors fall short. The downside is the metal may burn its silicon base while in use, which will increase the cost to maintain the product.(Ratnakar) The up side is whenever sunglasses pass the first test, the magnesium zinc oxide does not even need to be used, and therefore does not contribute to wearing it out. In addition, LED technology is increasing and as lower wavelengths are attainable in, the magnesium zinc oxide becomes even more effective than other detectors. This happens because this detector works with wavelengths much lower than conventional detectors. The data from this part will be sent to the RAM.

The RAM houses immediate data that will be used while the machine is running. The RAM communicates with the CPU to create the results and convert them into a form that humans can read. The ROM will house the software and functions needed by the CPU to calculate the results. The results are then sent to be displayed to the user.

We decided the best way to display the results would be an LCD screen. They are both cheap and effective at displaying simple alphanumeric terms. (Vorne) If the product is under budget, we also consider adding a printout within the system so the results can be documented instead of being lost once the machine is powered off. This leads to the next decision, the power source.

A simple AC adapter, or Switch-mode power supply (SMPS), would be able to supply efficient power to run our product. (Foutz) Once specific part numbers and amount of parts are brought to light, we can calculate the amps and voltage needed for the adapter.

Using these parts is the most efficient way to create this product for the consumer base. LEDs offer affordable wide-ranged UV light. The mirrored tubes will ensure the light is delivered to the sunglass lens. The dual detectors allow for accurate tests. Our software, computation, and display are being handled with the lowest cost possible without sacrificing quality. The end result of our collaboration is a high quality machine that is affordable for the large retail sunglass market, and allows for great profits to the maker, and seller of the product itself.

Design Requirements

Functional Performance Requirements

From start to finish, the machines will be emitting a UV ray through mirrored tubing directed towards the sunglass lens. Any remaining light will then continue into the sensor to be measured. If there is no remaining light, the sub-pico meter will not react, meaning the lens is 100% UV resistant. The processor will send this result to the LCD screen to be displayed to the user. If the sub-pico meter reacts, it will be moved by a motor and the magnesium zinc oxide sensor will be activated and moved into place. This detector can measure the amount of UV light received. The UV light activates the sensor that enhances the conductivity of the device. This change in voltage allows the processor to compute a reading of the intensity of UV detected. The processor then compares this to a calibrated number, and the resultant is displayed on the LCD screen to the user in a percentage.

The LEDs must be strong enough to penetrate the lens and be received by the sensor. One single-chip LED is capable of reaching 6,500 millicandela over a 6° arc. With this intensity, a chipset will have enough strength to surpass the necessary minimum. The sensor must be able

to detect any UV rays that pass through the lens. The machine as a whole must be able to be moved around within an office or store.

Operational-accessibility-usability Requirements

It is important that we produce a product that our customers can easily operate. The machine should come fully assembled and require only simple steps to begin. The product will have to be plugged in and calibrated. The calibration configuration will be programmed into the memory and the user will be prompted on what to do the first time the machine is powered on. This configuration is necessary so the CPU knows the amount of UV wavelengths being emitted by the LEDs. Next, the LCD screen must use a large enough font so that users with poor eyesight can still operate the machine with ease. The LCD screen will be 5 inches diagonally which is large enough to display 20 point or even larger font if necessary.

Marketing and Incidental Requirements

Aesthetics is an important factor in the economy for a product to be successful on the market. If an item does not look good, people will not want to buy it. We can apply this to our ultraviolet testing machine, and take into account some of the physical and visual qualities such as size, color and overall weight. There are many components to this machine; however, most are rather small in size. The largest section on the unit will be the compartment where the sunglasses can be mounted for testing. Although there are several parts to this machine, all of them will be placed in sequence and placed into a plastic cased box, giving it a sleek look. The testing machine starts with the source of UV radiation, light emitting diodes.

Our LEDs will be plugged into a bulb fixture that will hold about 40 small, single-chip LEDs. This holster will be mounted on the inside of the casing which will have a small hole where the cord will run to connect to the AC adapter for power. The AC adapter can be plugged into a normal wall outlet. Next, the mirrored tubing will connect over the LED fixture, leading into the compartment where the sunglasses can be placed on a mounting station. This compartment can be accessed by a small hinged cover, which can be pulled open to place the sunglasses on the mounting station. The tube ends right next to the stand where the sunglasses are placed. A circular rubber jacket can be placed onto the tube, and over the sunglass lens which will make sure no light will leak out from the tubing before reaching the lens. The second tube can be connected to the sunglasses the same way, having a rubber jacket also. This tube will run

directly to the sensors, which will be activated depending if there is any light remaining after being transmitted through the lens. Both sensors will be wired to the motherboard, containing the ROM, RAM, and CPU. This is all that the plastic casing will have inside.

On the outside, a flip-up, rotating, LCD screen will be wired to the microprocessor, which will be making the calculations. If the sub-pico meter reacts, this answer will run to the CPU, telling the LCD screen to show 100% effectiveness. However, if this sensor does not react, the magnesium zinc oxide will be activated and produce a voltage. This quantity will be read by the CPU, which will then make the calculation to wavelength intensity, and compare this to the designated source intensity. The CPU will calculate this percentage of change and that will be displayed on the screen as the effectiveness of the glasses. Also on the LCD screen will be an on-off button. This screen along with the rest of the testing unit will be made of a hard, white plastic. On the bottom of the plastic will be vents, which will let out the air pushed out by a ventilation fan placed on the inside, next to the mirrored tubing. This also will be powered by the AC adapter. The overall size of the testing unit will be 24 x 8 x 6 inches, giving it a volume of 1152 in³ or .667 ft³. Additionally, the entire machine will only weigh about 20 lb, making it easy to be carried and moved around.

Cost Constraints

Although the testing unit can work great and look good at the same time, it will not be a successful product if the price is too high. We chose each component for many specific reasons, one of which being the cost. Using estimated cost of each component from various vendors, we are able to estimate the overall cost to make the testing unit. However, there are also cost to actually produce this product and ship it to different businesses. Below is a chart showing the cost of each component and the estimated cost of the final product.

Material	Quantity	Cost
LEDs	40	\$75
Fixture	1	\$100
Mirrored Tubing	1ft.	\$25
Sub-Pico Meter	1	\$50
Magnesium Zinc Oxide	1	\$45
LCD Screen	1	\$40

AC Adapter	1	\$60
CPU & Motherboard	1	\$50
Plastic Cover	1ft. ³	\$30
Ventilation Fan	1	\$5
	TOTAL	\$480

This total plus all other costs, we estimated one final testing unit with production and shipping could cost only about \$550. Compare this to all other possibilities is an extremely inexpensive price. For instance, a single laser could cost up to \$400. Also, other detection sources can cost up to \$200. ^[3] All our components allow for a quality product for a reasonable price. When businesses start buying our item, production will increase. Usually it costs less to produce many items at one time, rather than just one at a time. This will cut down on costs, saving money for our business along with our consumers. We have designed a quality product at a quality price and we are excited to see what it can do.

Evaluation

Functional Tests

All components need to be calibrated in any testing device. For this machine, the first calibration will be done without sunglasses, but with a closed lens container. Our LED light source will be activated and shine the UV rays directly into the sensor. This will allow the computer to know the amount of UV the LEDs are emitting. The equation is as follows: $1 - (\text{light detected}) \times 100$. This will give us the percentage of UV rays blocked by the lens. The calibration gives us the “light emitted” and the standard sunglass tests provide the “light detected” variable. Calibrations should be run after a certain amount of uses. The following tests list the directions for proper use of the device.

Calibration

1. Open case, and adjust mirrored tubes so they are connected.
2. Close container top, assuring no outside light is let in.
3. On the display screen, press CALIBRATE
4. Wait until completion

Assure Proper Testing

1. Open case and place sunglasses with known 50% protection
2. Close container top
3. Press STANDARD TEST on display screen
4. Wait for results on display
5. Display should read roughly 50% protection
6. If results are skewed, contact manufacturer

Testing

1. Open case and place sunglasses on mount.
2. Adjust mirrored tubing to fit the lens.
3. Close container top
4. Press STANDARD TEST on display screen
5. Wait for result on display
6. Remove sunglasses from container

NOTE: A touch sensor on the door of the enclosure can be used to warn the user if the container is not closed properly.

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