Understanding VCSELs and LEDs in Sensing Applications

Application Bulletin 227

- Advantages and disadvantages of VCSELs and LEDs
- LEDs and VCSELs in transmissive switches
- LEDs and VCSELs in reflective switches

Advantages and disadvantages of VCSELs and LEDs

The purpose of this application bulletin is to provide a basic understanding between IR-LED (Infrared - Light Emitting Diode) and a IR-VCSEL (Infrared - Vertical Cavity Surface Emitting Laser). In both of these products it is required that the designer understand these components operate on a current flow rather than a reference voltage applied across the anode and cathode (figure 1). The following will detail the comparisons and differences of the LED and VCSEL in various discrete and optical switch designs.

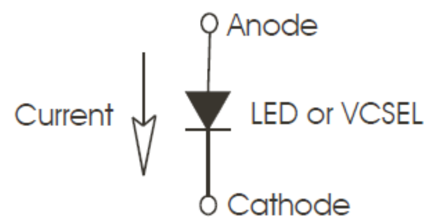

Figure 1

A typical current range for an LED is between 5 mA (milliamperes) and 100 mA. In order to get sufficient on axis power (Power directed toward a specified location) the LED may be pulsed with currents in excess of 1 A. Concern must be taken not to exceed the average power dissipation of the package. By using an LED and VCSEL in a similar package without a lens a good comparison can be achieved to demonstrate the differences between the devices. As shown in the Ee (optical power) versus IF (forward current) (see figure 2) the current for an LED is mostly linear from 2 mA to 50 mA where the VCSEL doesn't turn on until after a specified current level (typically between 3 mA and 5 mA). This is known as the threshold current (ITH) for the device. Each VCSEL design has its own threshold current and is dependent on the structure, speed, wavelength and output power of the device. LED optical power is measured as "Total Power" or "Apertured Power" at a specified distance. "Apertured Power" is typically specified in mW/cm2 (milliwatts per centimeter squared) or mW/Sr (milliwatts per steradian) (see Optek Application Bulletin 222 for conversion information) while VCSEL power is measured as "Total Power" or "Coupled Power" (apertured power into a specified Fiber Optic cable, 50 micron, 62.5 micron etc.).

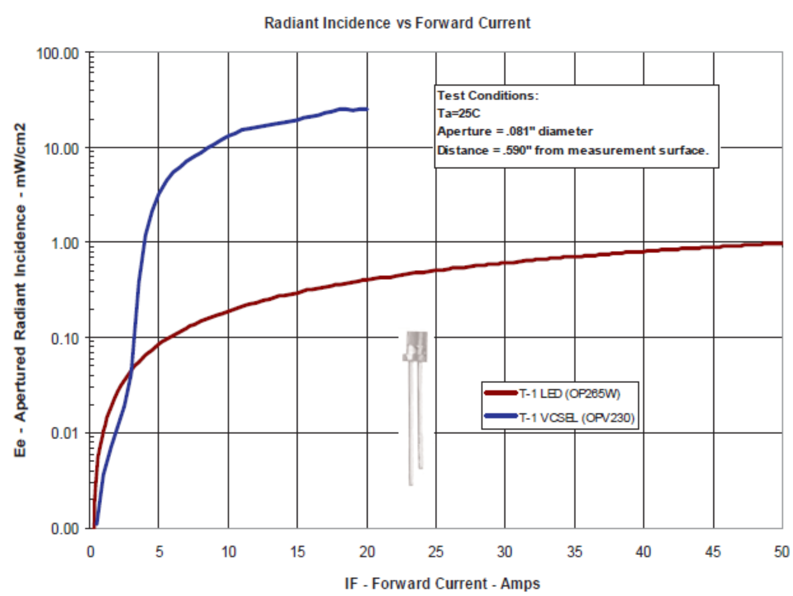

Figure 2

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In order to view the difference between the LED and VCSEL optical power, the On Axis Power (Ee) is plotted on a logarithmic scale and the Forward Current (IF) is plotted on a linear scale. The forward currents used for figure 2, is 0 mA to 50 mA for the LED and 0 mA to 20 mA for the VCSEL. These are the preferred ranges of forward current to provide very high reliability products and meet power dissipation considerations. At very low currents, below the threshold current of the VCSEL, the LED has a better output power than the VCSEL. After reaching the threshold current of the VCSEL, it's on axis optical power is much greater than that of the LED. With the VCSEL forward current between 5 mA and 20 mA, the VCSEL's apertured power is approximately 67 times that of the LED. Looking closer at the drive currents at both 10 mA and 20 mA, apertured power difference is significant. At a drive current of 10 mA the apertured optical power ratio between the VCSEL and LED is approximately 70:1. At 20 mA this same ratio changes to approximately 64:1.

A flat lens device was chosen for the test to show the true characteristics of the device and minimize the influence of the package. At half power point for a Flat Lens (T-1) LED, the total inclusive angle is 60° and the power is relatively flat across the entire area (see figure 3). Figure 4-A shows the typical characteristics that can be expected from a VCSEL in a Flat Lens (T-1) package with an inclusive half power angle of less than 12°. A typical VCSEL power plot shows spikes in the power range, with an average aperture power of typically 65 times that of an LED. This allows the VCSEL to enhance the operation in many transmissive and reflective switch applications. When a lens is put on the LED or VCSEL the optical power beam is narrowed depending on the lensing parameters. When a TO-46 package with an optical lens (see the OP231 and OPV202 data sheets), the half power beam angle is reduced to less than 18° for the LED and less than 2° for the VCSEL (Figure 4-B), thus increasing the on axis apertured power greatly.

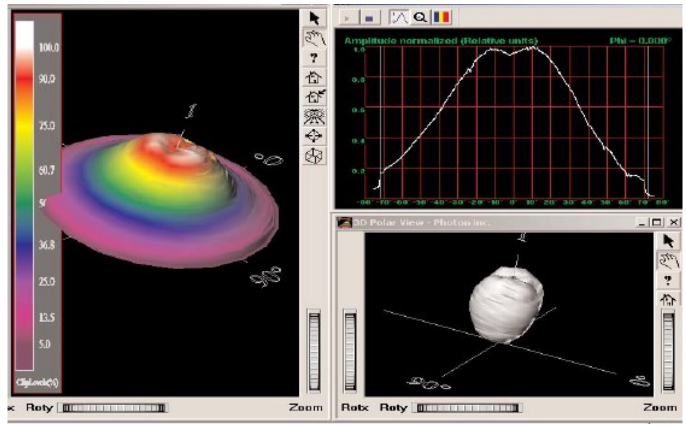

Figure 3 (LED - Flat Lens)

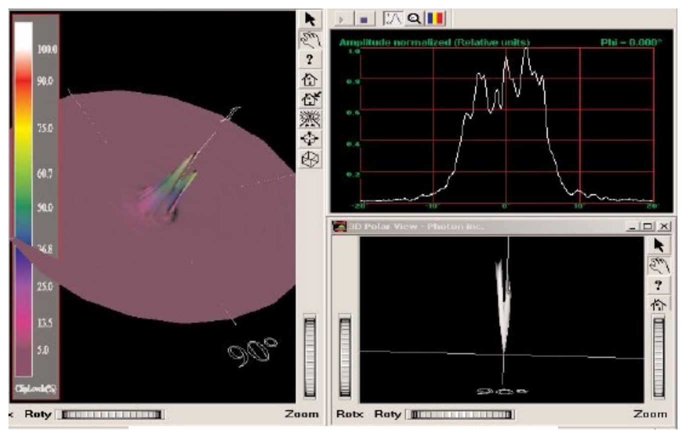

Figure 4-A (VCSEL- Flat Lens)

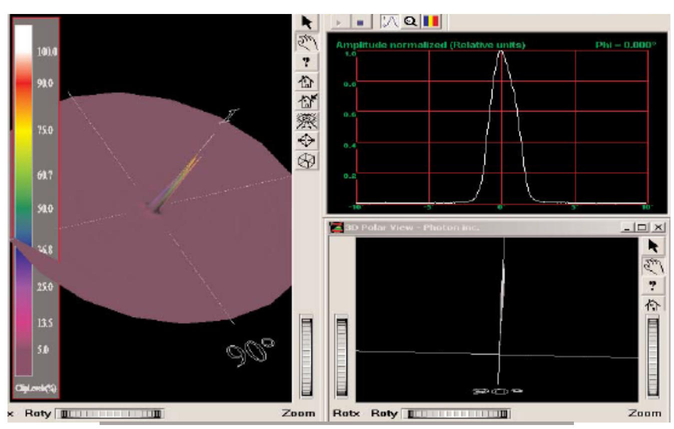

Figure 4-B (VCSEL - Dome Lens)

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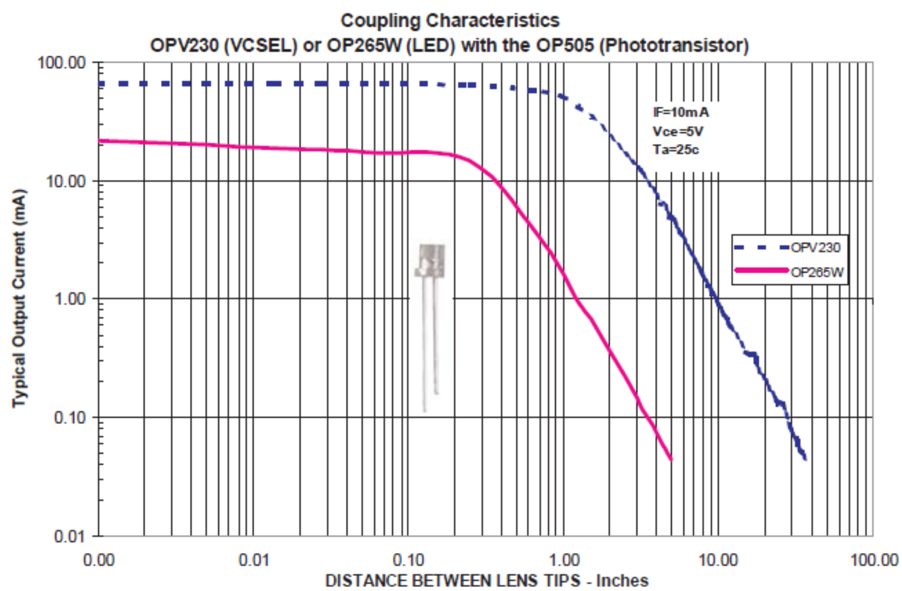
LEDs and VCSELs in Transmissive Switches

Transmissive optical switches are sometimes known as interrupter or slotted switches. The concept of a transmissive switch is to allow a light signal to strike a optical receiver sensor and break the optical beam when an object is to be detected in the optical path. Some uses for a transmissive switch are for encoders, safety and security shielding, and object sensing. The typical light emitting device in the industry has been the infrared (IR) LED. With the invention of the VCSEL, this may change for some applications. As noted in the previous section on the major differences between the LED and VCSEL, the VCSEL has a greater on axis power in relation to the LED. This means that for a much lower current, the usable optical power from a VCSEL, with a narrower beam angle than the LED, is greater than an LED. This provides the ability to operate optical devices for greater distances as well as lower drive currents. Keep in mind that a VCSEL has a threshold current that must be achieved before the benefits of the device can be realized.

A typical transmissive switch utilizing an LED and high drive currents, up to 100 mA, has a useful distance up to 5 inches (0.13 meters). The use of a VCSEL can extend the typical distance up to 3 feet (0.9 meters). With the addition of an SDD (Synchronous Driver Detector) and proper lens, the distance can be increased up to 3 feet (0.9 meters) for a LED and 20 feet (6.1meters) for a VCSEL. The SDD has an additional advantage of minimizing the affect from ambient light by pulsing the system and looking for a change in the light level.



(Figure 5)

Figure 5 shows the coupling relationship between an LED (OP265W), and VCSEL (OPV230) driven at 10 mA coupled to a Phototransistor (OP505). This is basically a transmissive switch utilizing a phototransistor. Another popular sensor is a Photologic® (optical sensor with a logical, high or low, output) device reducing the additional electronics needed to interface with standard electrical interfaces. The IC(ON) of the Phototransistor shows the usable current available for additional electronics. With the use of a VCSEL the drive current can be reduced to the 5 mA range allowing this device to easily be used in battery operated applications. An additional benefit that the VCSEL brings is the turn on and turn off speed of the device. Rise and Fall times for a VCSEL are in the 200 picosecond range with 500 nanoseconds being typical for an LED. With the addition of the rise and fall times in the 200 ps range and the forward current requirement of 5 mA, the VCSEL is the optimum device to be used in any battery driven applications.

Looking at the optical power beam plot for both the LED and VCSEL (see figures 3 & 4) , the LED is much easier to align to a remote target and is much more consistent in power across the emitting area than the VCSEL. The beam pattern of the VCSEL shows major peaks and valleys therefore the output of the sensing device can vary greatly with minimal shift in alignment. For short distances and with the use of Photologic® devices, this effect should be minimized.

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Whenever high optical power is present, the fall time of the receiver may become a concern and a special aperture (blocking some of the light) may be required to optimize the performance of the transmissive switch. Whenever using an optical device for switching, the sensor should be protected against ambient light, thus increasing the ability to recognize the emitted light from the optical device (LED or VCSEL).

LEDs and VCSELs in Reflective Switches

A reflective optical switch is a device that shines IR light on an object and looks for a reflected signal. These type switches can be used as object sensors as well as bar code readers. The ability to distinguish levels of reflectivity define the size of the bar code that can be determined.

Light is emitted from an LED or VCSEL and the light is reflected off a surface for the sensor to detect. The sensor can be a Phototransistor, Photologic® or SDD device depending on the characteristics of the application. Reflective switches are either focused or non-focused. A focused switch has both the emitting and sensing device pointing to a spot at "D" distance from the surface of the device. The focused switch is generally used for recognition of any surface that will reflect light back to the sensor. These may include object sensing and bar code reading applications. A non-focused switch is generally used for sensing the presence of an object. The reflective distance for a OPB608 type non-focused reflective switch is shown in figure 6. The usable distance with 12 mA drive current is 0.2 inches and increases to 0.3 inches when the drive current is 20 mA. By putting a VCSEL in the same package, the useful reflective distance at 12 mA drive current is 0.8 inches and increases to 1.0 inch with 20 mA. Therefore, the addition of a VCSEL in a non-lensed, non-focused switch can increase the usable reflective distance up to 4 times that of an LED.

Bar code applications require a optical small spot or consistent light source similar to that of the OP265. The beam analysis of the OPV230 (see figure 4) shows many optical power peaks and valleys therefore it may not be the optimum light source for a bar code scanner. A VCSEL device can and should be used if lensed properly to give a high intensity light spot. This addition of lensing may change the laser safety category from a class 1M to a class 3B or higher (Laser safety will be discussed later). The focused VCSEL's can be kept in the 1M range if the drive current is controlled to maintain an acceptable power level. Restricting the viewing by assembling the VCSEL in a housing, such as in a transmissive switch may also meet the laser safety requirement. By fully enclosing the part in a housing that prevents direct viewing of the VCSEL, the laser safety requirement is also achieved.

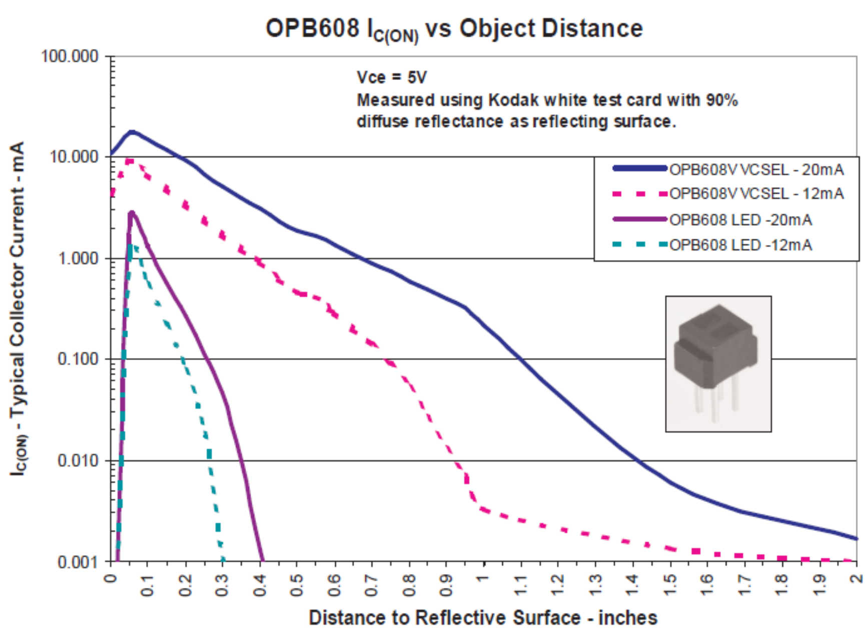

Figure 6

All the analysis in the article has been performed on a non-lensed VCSEL and LED in order to keep the data consistent as well as maintain a class 1M laser safety rating. Much greater power can be obtained with VCSEL's that are focused for specific applications.

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