VCSELs vs. LEDs in sensing apps

The designer must be aware of the differences when choosing between the two technologies

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A light source is required for many sensing applications, and knowing the differences between solutions make device selection easier. 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 two.*

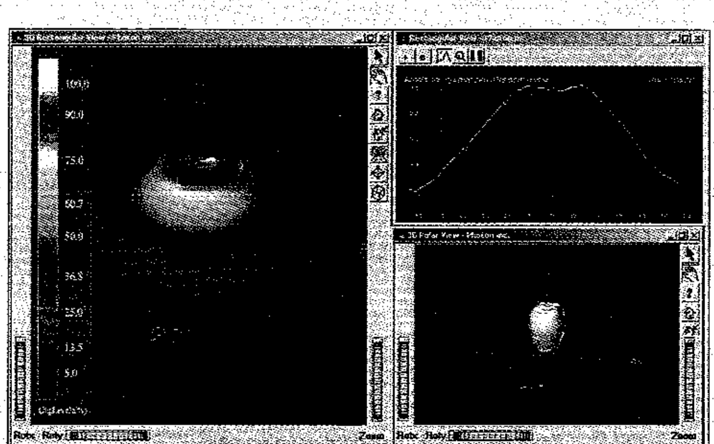

Fig. 1. At the half-power point for a flat lens (T-1) LED, the total inclusive angle is 60° and the power is relatively flat across the entire area.

Optical power vs. forward current

A typical current range for an LED is between 5 and 100 mA continuously, and to get sufficient on-axis power 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.

When looking at optical power (E_e) versus forward current (I_F), the current for an LED is mostly linear from 2 to 50 mA, where the VCSEL doesn't turn on until after a specified current level typically between 2 and 5 mA. This is known as the threshold current (I_{TH}) for the device. Each device has its own threshold current and is dependent on the structure, speed, wavelength, and output power.

LED optical power is measured as "total power" or "apertured power" at a specified distance. "Apertured power" is typically specified in milliwatts per centimeter squared or milliwatts per steradian, while VCSEL power is measured as "total power" or "coupled power."

To view the difference between the LED and VCSEL optical power, the on-axis power (E_e) is plotted on a logarithmic scale and the forward current (I_F) is plotted on a linear scale. The forward current used is 0 to 50 mA for the LED, and 0 to 20 mA for the VCSEL.

At very low currents, the LED has a better output power than the VCSEL, but once a VCSEL reaches its threshold current, its on-axis optical power is much greater than that of the LED. With the VCSEL forward current between 5 and 20 mA, the VCSEL's apertured power is approximately 67 times that of an LED.

Looking closer at the drive currents at both 10 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.

At the 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 *Fig. 1*), while a VCSEL in a flat-lens (T-1) package with an inclusive half-power angle of less than 12° shows spikes in the power range (see *Fig. 2*).

This allows the VCSEL to enhance operation o many transmissive and reflective switch applications using minimal current. When a lens is put on the LED or VCSEL, the optical power beam is narrowed, depending on the lensing parameters.

* The analysis conducted in this article has been performed on a nonlensed vertical-cavity surface-emitting laser (VCSEL) and LED to keep the data consistent as well as to maintain a class 1M laser safety rating. Much greater power can be obtained with VCSELs focused for specific applications.

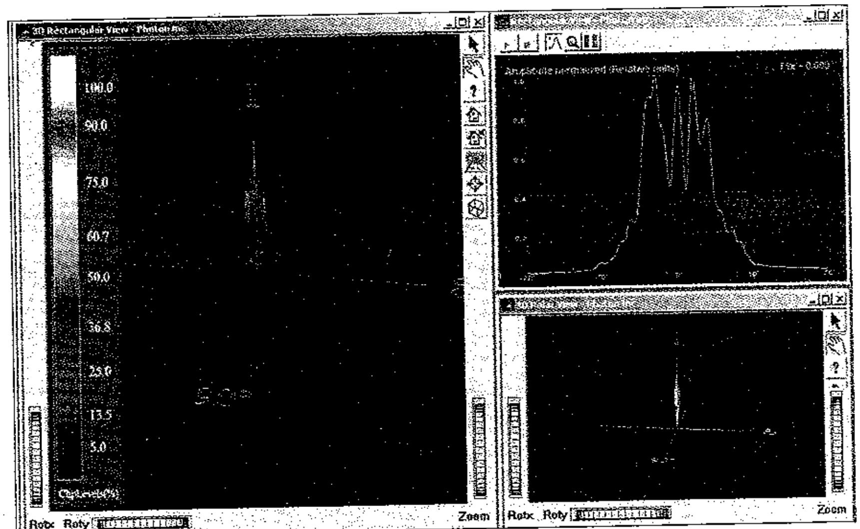

Fig. 2. A VCSEL in a flat-lens (T-1) package with an inclusive half-power angle of less than 12° shows spikes in the power range.

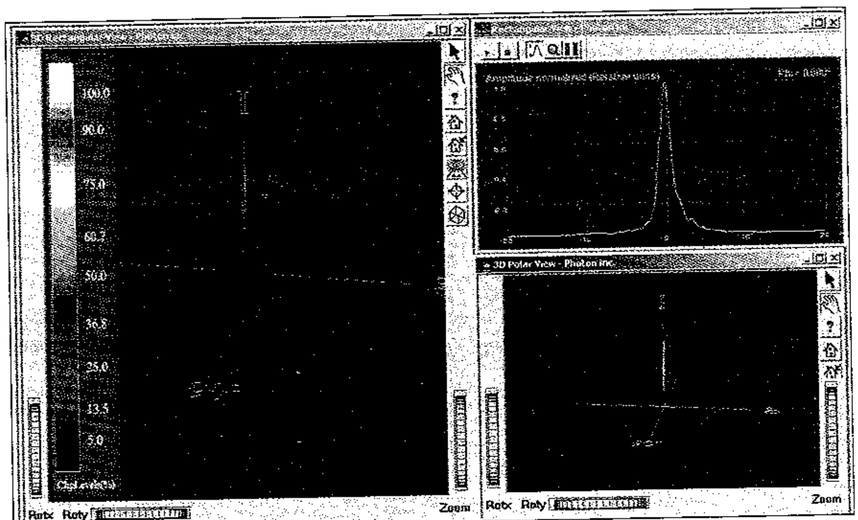

Fig. 3. Using a TO-46 package with an optical lens increases the on-axis power.

Using a T-1 package with an optical lens, the half-power beam angle is reduced to less than 18° for the LED and less than 2° for the VCSEL, thus greatly increasing the on-axis apertured power (see *Fig. 3*).

LEDs and VCSELs in transmissive switches

Used in encoders, safety and security shielding, and object sensing, transmissive optical switches are sometimes known as interrupter or slotted switches. The typical light-emitting device in the industry has been the infrared LED, but a 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 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 using an LED and a drive current up to 100 mA has a useful distance up to 5 in. By using a VCSEL, typical distance up to 3 ft can be achieved.

With the addition of a synchronous driver detector (SDD) and proper lens, the distance can be in-

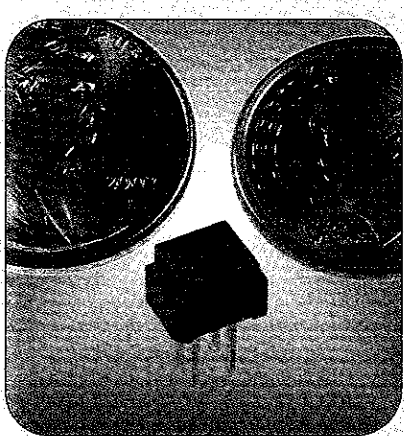

Fig. 4. A nonfocused switch such as this OPB608 is generally used for sensing the presence of an object.

creased up to 3 ft for a LED and 20 ft 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.

LEDs and VCSELs in reflective switches

Used as object sensors as well as in bar code readers, a reflective optical switch is a device that shines IR light from an LED or VCSEL on an object and looks for a reflected signal, distinguishing levels of reflectivity to define the size of the bar code that can be determined. The sensor can be a phototransistor, Photologic (optical sensor with a logical-high or logical-low output), or SDD device, depending on the characteristics of the application.

Reflective switches are either focused or nonfocused. 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 bar code and encoder applications.

A device such as the OPB608 Series nonfocused reflective switch has a usable distance with a 12-mA drive current of 0.2 in., increasing to 0.3 in. at 20 mA. By putting a VCSEL in the same package, the useful reflective distance at 12 mA drive current is 0.8 in. and increases to 1.0 in. at 20 mA (see *Fig. 4*). EP