Characteristics of IREDs

Measurement of Power Output

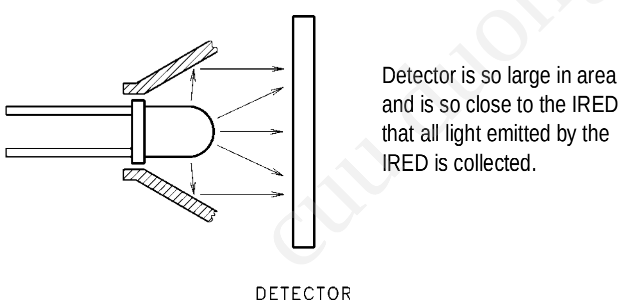
It is standard industry practice to characterize the output of IREDs in terms of power output. Since the amount of light an IRED generates depends on the value of the forward drive current (I_F), the power output is always stated for a given value of current. Also, the ambient temperature must be specified inasmuch as the radiant power decreases with increasing temperature, power decreases with increasing temperature, typically -0.9%/°C.

The following two methods are used to measure light power output.

Total Power (P_O)

This method involves collecting and measuring the total amount of light emitted from the IRED regardless of the direction. This measurement is usually done by using an integrating sphere or by placing a very large area detector directly in front of the IRED so that all light emitted in the forward direction is collected. The total output power is measured in units of watts.

The total power method ignores the effect of the beam pattern produced by the IRED package. It cannot predict how much light will strike an object positioned some distance in front of the IRED. This information is vital for design calculations in many applications. However, total output power measurement is repeatable and quite useful when trying to compare the relative performance of devices in the same type of package.



Measuring Total Power - All Light is Collected

On Axis Power (P_A)

This method characterizes the IRED in terms of axial intensity. Many practical applications require knowledge of what percentage of IR power emitted is incident upon a detector located at some distance in front of the IRED. In order to achieve repeatable and meaningful measurement of this parameter it is necessary that the distance from the IRED to the detector and the active area of the detector be specified. This is because the radiation pattern observed for many IREDs is dependent on the distance from the IRED.

For many of its emitters PerkinElmer Optoelectronics states a minimum irradiance (E_e), which is the average power density in milliwatts per square centimeter (mw/cm^2) incident onto a surface of diameter (D) at a distance (d). The irradiance will in general not be uniform over this whole surface, and may be more or less intense on the optical axis. Irradiance at other distances may be determined from the graphs showing irradiance versus distance.

The on-axis power can also be stated as a radiant intensity (I_e) which is the average power per unit of solid angle expressed in units of milliwatts per steradian (mW/sr). To calculate the irradiance at any distance the following formula is applicable.

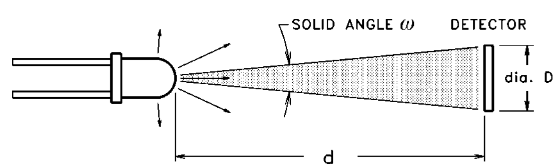
$$E_e = I_e/d^2 \text{ (mW/cm}^2\text{)}$$

where:

I_e = radiant intensity (mW/sr)
d = distance (cm)

However, it should be noted that the IRED cannot be treated as a point source when the spacing between the IRED and receiver is small, less than ten times the IRED package diameter. Attempts to use the inverse square law can lead to serious errors when the detector is close to the IRED. Actual measurements should be used in this situation.

For IREDs of any particular package type there is a direct relationship between all three methods used for specifying power output. However, imperfect physical packages and optical aberrations prevent perfect correlation.



Detector or area (A) is located at specified distance (d) in front of the IRED being measured.

Measuring On-Axis Power

Characteristics of IREDs

Efficiency vs. Drive Current

As mentioned in the section *What is an LED? What is an IRED?*, once injected carriers cross the junction they can recombine by a radiative process which produces light or by a nonradiative process which produces heat. The ratio between these two processes is dependent on the current density (Amps/cm^2 of junction area).

At low current densities (.1A/cm^2) the nonradiative processes dominate and very little light is generated. As the current density is increased the radiative mechanisms increase in efficiency so that a larger and larger percentage of the forward current will contribute to the generation of light. At sufficient current densities, the percentage of forward current which produces light is almost a constant. For an IRED of “average” junction area (0.015" x 0.015") this region of linear operation is in the range of approximately 2 mA to 100 mA. Also, at high forward drive currents the junction temperature of the chip increases due to significant power dissipation. This rise in temperature results in a decrease in the radiative recombination efficiency. As the current density is further increased, internal series resistance effects will also tend to reduce the light generating efficiency of the IRED.

Light Output Degradation

In normal operation, the amount of light produced by an IRED will gradually decrease with time. The rate of decrease depends on the temperature and the current density. IREDs driven at low forward currents at room temperature ambient will degrade more slowly than IREDs driven at higher forward drive currents and at elevated temperatures. Typical degradation data is presented in the data sheet section.

Light output degradation is caused by stress placed on the IRED chip, be it mechanical, thermal or electrical. Stress causes defects in the chip to propagate along the planes of the chip’s crystalline structure. These defects in the crystalline structure, called dark line defects, increase the percentage of non radiative recombinations. Forward biasing the IRED provides energy which aids in the formation and propagation of these defects. The designer using IREDs must address the light output degradation with time characteristic by including adequate degradation margins in his design so that it will continue to function adequately to the end of the design life.

Peak Spectral Wavelength (λ_P)

IREDs are commonly considered to emit monochromatic light, or light of one color. In fact, they emit light over a narrow band of wavelengths, typically less than 100 nm.

The wavelength at which the greatest amount of light is generated is called the peak wavelength, λ_P. It is determined by the energy bandgap of the semiconductor material used and the type of dopants incorporated into the IRED. The peak wavelength is a function of temperature. As the temperature increases, λ_P shifts towards longer wavelengths (typically 0.2 nm/°C).

Forward Voltage (V_F)

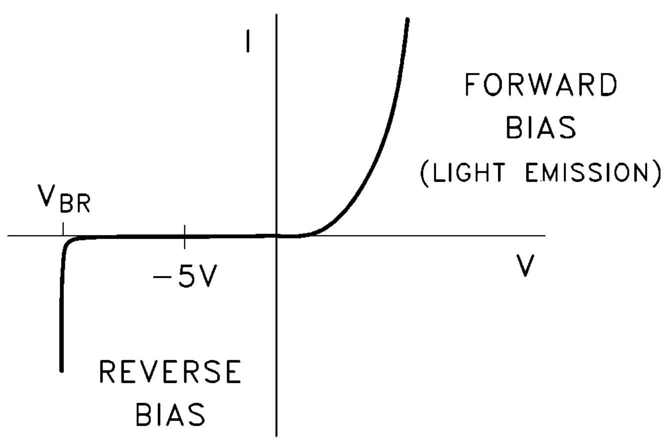
The current-voltage characteristics of IREDs, like any other PN junction device, obeys the standard diode equation.

$$I_F = I_O[e^{qV_F/nKT} - 1]$$

V_F is the voltage drop across the IRED when it is forward biased at a specific current, I_F. It is important to note that V_F is a function of temperature, decreasing as temperature increases. Plots of V_F vs. I_F as a function of temperature are included in the data sheet section.

Reverse Breakdown Voltage (V_{BR})

This is the maximum reverse voltage that can safely be applied across the IRED before breakdown occurs at the junction. The IRED should never be exposed to V_{BR} even for a short period of time since permanent damage can occur. PerkinElmer IREDs are tested to a reverse voltage specification of 5V minimum.



Characterizations of IREDs

Power Dissipation

Current flow through an IRED is accompanied by a voltage drop across the device. The power dissipated (power = current x voltage) causes a rise in the junction temperature rise is a decrease in the light output of the IRED (approximately -0.9%/°C). If the junction temperature becomes too high, permanent damage to the IRED will result. The maximum power dissipation rating of a semiconductor device defines that operating region where overheating can damage the device.

In any practical application, the maximum power dissipation depends on: ambient temperature, maximum (safe) junction temperature, the type of IRED package, how the IRED package is mounted, and the exact electrical drive current parameters.

While the IRED chip generates heat, its packaging serves to remove this heat out into the environment. The package's ability to dissipate heat depends not only on its design and construction but also varies from a maximum, if an efficient infinite heat sink is used, to a minimum, for the case where no heat sink is present.

The thermal impedance rating of the package quantifies the package's ability to get rid of the heat generated by the IRED chip under normal operation.

Thermal impedance is defined as:

$$\theta_{JA} = (T_J - T_A) / P_D \qquad °C/W$$

where:

θ_{JA} = thermal impedance, junction to ambient
T_J = junction temperature
T_A = ambient temperature
P_D = power dissipation of the device

By definition θ_{JA} assumes that the device is not connected to an external heat sink and as such represents a worse case condition in as far as power dissipation is concerned.

For plastic packages and non-heat-sunk hermetics:

$$\theta_{JA} \equiv 400°C/W$$

Example: A hermetic LED is driven with a forward current of 20 mA dc. At this drive current the forward voltage drop across the IRED is 1.5 volts.

P_D = (.020 A) x (1.5 V) = .030 W
ΔT = (400°C/W) x (.030 W) = 12°C
(–0.9%/°C) x 12°C) $\cong$ -11%

There is an 11% decrease in the amount of light generated by the IRED.

For hermetics with good heat sinking:

$$\theta_{JC} \cong 150°C/W$$

where:

θ_{JC} = thermal impedance, junction to case
ΔT = (150°C/W) x (.030 W) = 4.5°C
(–0.9%/°C) x (4.5°C) $\cong$ -4%

There is only a 4% decrease in the amount of light generated by the IRED when a heat sink is used.

This is a clear example of the law of diminishing returns: increasing the forward drive current will increase the amount of light generated by the IRED. However, increasing the drive current also increases the power dissipation in the device. This raises the IRED's junction temperature resulting in a decrease in the IRED's efficiency.

One way to overcome this performance limiting characteristic is to pulse the IRED on and off rather than driving it with a dc current. Maximum light output is obtained because the average power dissipated is kept small. Above 100 mA of drive current it is advisable to limit the maximum pulse width to a few hundred microsecounds, and a 10% duty cycle.