Understanding infrared diode power ratings.

Introduction

Infrared emitting diode power measurement is dependent upon a number of variables which must be precisely defined in order for design engineers to utilize data sheet information. Manufacturers differ not only in the techniques used in measuring power, but also in their interpretations of the definitions of the parameters which are measured. This application bulletin is intended to clarify this misunderstanding, especially for GaAs and GaAlAs solution grown epitaxial devices.

General Discussion

Power is measured in units of energy per unit of time, and the conventional MKS unit is the Watt. Some factors which must be controlled to make accurate power measurements are discussed below.

The energy an LED emits is in the form of photons, and a photon's energy is inversely proportional to its wavelength. To measure the power emitted, the technique must take into account both the rate of photon emission and the average wavelength of the photons. Both the rate emission of the LED chip and the average wavelength of the emitted photons change as functions of chip temperature. See Figures 1 and 2 for examples of this change.

Figure 1. Output Power vs. Ambient Temperature for both GaAs and GaAlAs IR LEDs

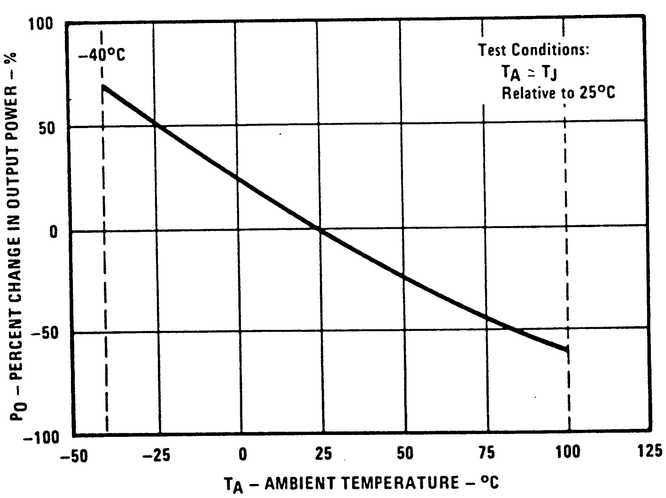
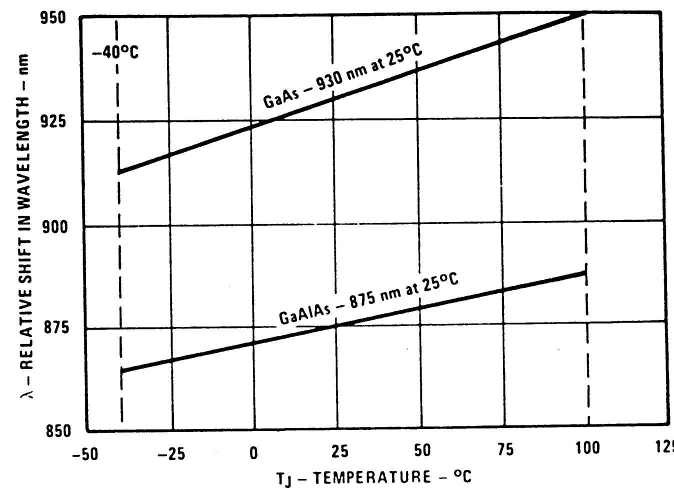
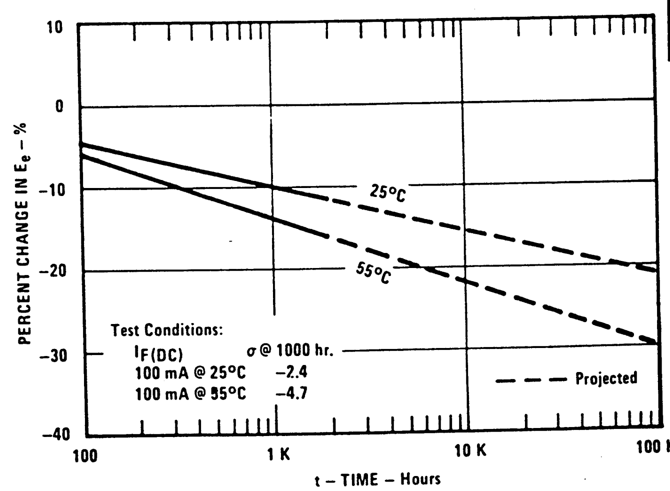


Figure 2. Peak Wavelength vs. Ambient Temperature for both GaAs and GaAlAs IR LEDs



Stress on the chip will cause any defects in the chip to expand along the planes of the crystalline structure in a process called dark line defect formation. This degrades the chip, and power output decreases as a function of time. Measurements made after the chip has been stressed mechanically, thermally, or electrically will be lower than initial readings. Figures 3, 4, and 5 illustrate the magnitude of this change due to applied DC current for variations of ambient temperature, current level, and different materials used as emitters.

Figure 3. Percent Change in GaAs IR LED Mounted in Metal TO-46 Package vs. Time at 25°C and 55°C



APPLICATION BULLETINS

Figure 4. Percent Change in GaAlAs IR LED Mounted in Plastic TO-46 Package vs. Time at Various Current Levels

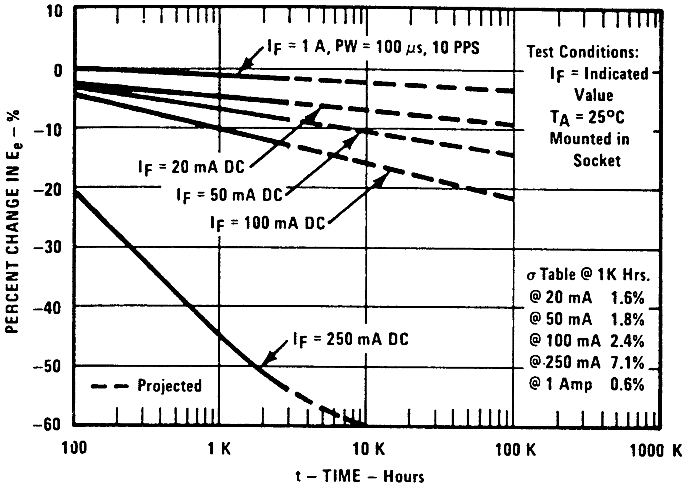
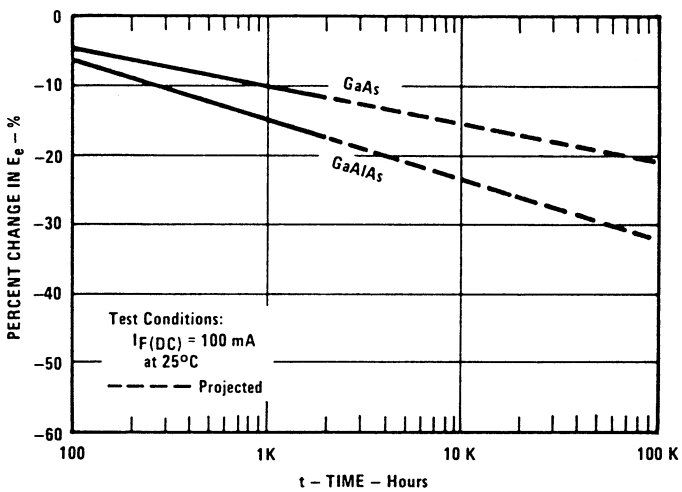


Figure 5. Percent Change in GaAs and GaAlAs IR LED Mounted in Metal TO-46 Package vs. Time under Same Conditions

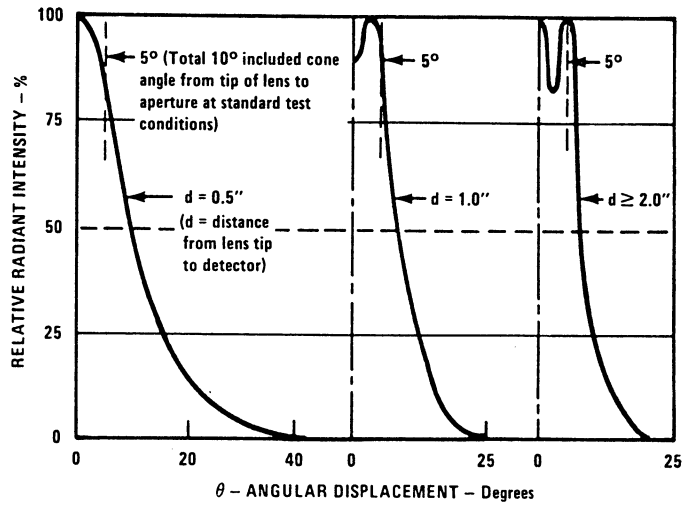


The response of most detectors is also wavelength and temperature dependent. The surface of the detector can reflect photons depending upon the wavelength, the angle of incidence, and the type of protective coating on the detector surface. The range of linearity in power detection can be exceeded by some emitting devices. Also, there are other minor characteristics of detectors which must be considered. Obviously, the accuracy of the detection system is critically important.

Any measurement of directed output is dependent upon complex optics which include chip centering in the reflective cup, reflector design, chip to lens centering, bubbles or contaminants in the packaging, and the fact that approximately half of the emitted photons exit the chip from the side walls rather than the top surface.

Many devices have radiation patterns which change as the distance from the device to the detector is varied, so this distance can be important in directed output measurement. See Figure 6:

Figure 6. OP295/OP296/OP297 Relative Radiant Intensity vs. Angular Displacement



It is essential that these variables be exactly specified in order for users to extract necessary information from data sheets. Separate application bulletins address the thermal behavior of LEDs (Bulletins 105 and 121) and the characteristics of GaAs and GaAlAs LEDs (Bulletin 114). Power measurement is integrally tied to the information contained in these bulletins, and even a basic understanding is difficult without understanding the information they contain.

Parameter Definitions and Measurement Techniques

There have traditionally been two methods of defining power measurement, but there have been different interpretations for each.

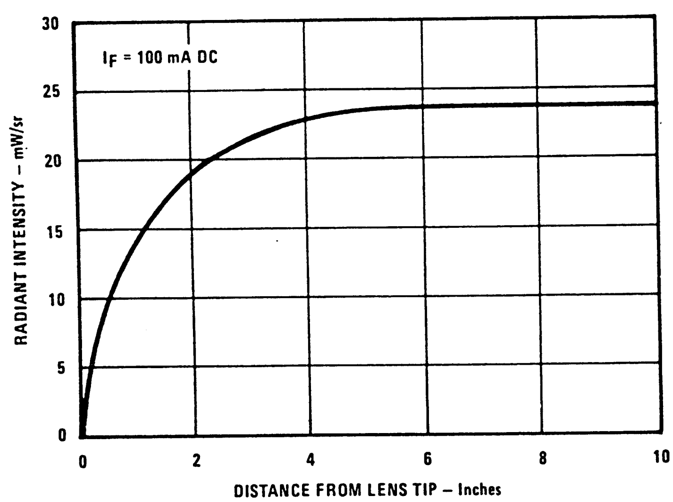
The first method is radiant power output (P_O or E_e), sometimes called total power. A strict interpretation of P_O is that the total amount of radiation exiting the package in any direction should be measured. Optek has interpreted radiant power output to be only that radiation which exits the package in a direction useful to most customers. The measurement includes only that radiation collected by a flat surface detector near the lens tip and orthogonal to the lens axis. Radiation emitted from the sides or back of the package and surface reflections from the detector are not collected. Therefore, Optek devices are conservatively rated (sometimes by a factor of 2 depending on the device type) when compared to devices which are measured differently by other manufacturers. For instance, P_O readings for the narrow (15° between half power points) radiation pattern OP295 are typically 60% higher when using a parabolic reflector than when using the standard Optek P_O test fixture.

P_O measurements are normally useful only for devices which have wide radiation patterns because the primary application is in providing a relatively even intensity over a large area. Radiation which exits the side or back of the package is not useful without external reflectors; and if external reflectors are added, there are intensity peaks in the radiation pattern which are detrimental in most applications.

The second major way to measure power is on-axis intensity. This is done by measuring the power incident upon a specified area. The most common method is to provide a fixture which has a fixed distance from the device to an aperture of precisely known area which is placed in front of a detector. This measured power can then be specified as average power per unit area (both $E_e(APT)$ and P_A are equivalent and the unit of measure is normally mW/cm^2) or as average power per unit cone angle (I_e; where the unit of measure is mW/sr).

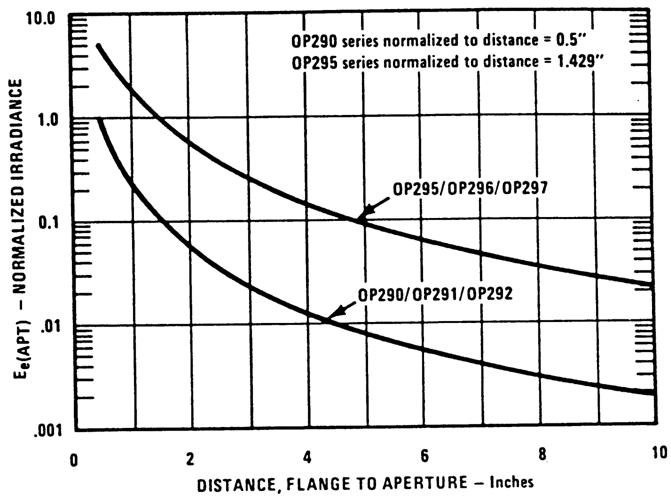
Most LEDs cannot be modeled as a point or discrete source except at distances which are very large compared to the package dimensions and/or optical dimensions. Thus, the foundation assumption in spherical calcaulations (using mW/sr) is invalid and attempts to use this model can lead to errors. Therefore, the calculated value of I_e is dependent upon distance for most applications, and a design engineer can be misled by the mathematical model into assuming that I_e is a constant regardless of distance. Note in Figure 7 how the mW/sr becomes consistent at approximately 6 inch separation.

Figure 7. Output Intensity in mW/sr vs. Distance from Lens Side of Mount Flange on T–1 3/4 Package



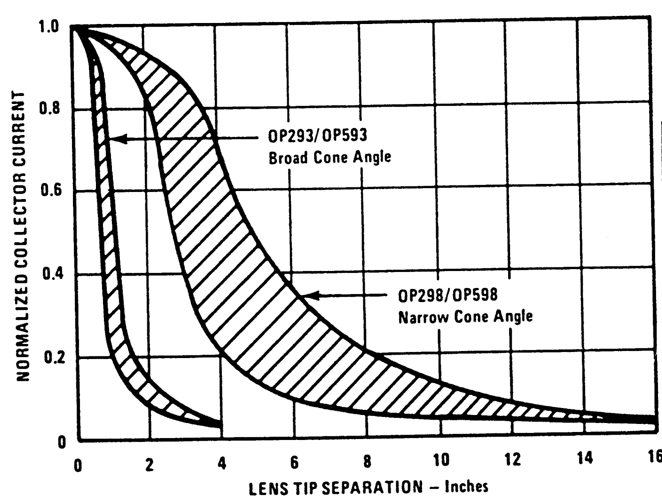
Optek has chosen to use $E_e(APT)$ or P_A rather than I_e for devices which don't have a virtual source that is distance independent. This is the preferred parameter because a simple performance graph can then show how $E_e(APT)$ varies with distance as shown in Figure 8.

Figure 8. Output Intensity in mW/cm^2 vs. Distance from Lens Tip on T–1 3/4 Package



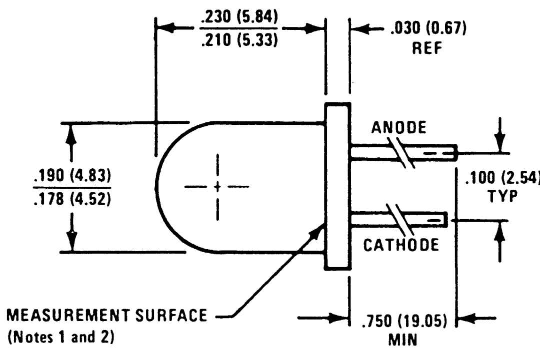
$E_e(APT)$ measurements have historically been made only for narrow radiation pattern devices because their major application is to have a high on-axis intensity for good coupling efficiency with a small sensing area photodetector (see Figure 9).

Figure 9. Coupling Characteristics of Plastic TO-46 Phototransistor and GaAlAs IR LED vs. Separation Between Lens Tips



However, Optek is now using the measurement parameter with wide radiation pattern devices also. $E_e(APT)$ is a key design parameter when the distance and aperture are chosen to give maximum useful information. The distance is chosen so two criteria are met: first, all intensity peaks should fall within the aperture opening for devices with normal optics; and second, the distance should be at a maximum with the constraint that the intensity does not vary more than 10% from point to point within the aperture opening for normal devices. Aperture size is typically chosen so that it is slightly larger than the lens diameter of a detector which is mechanically matched to the dimensions of the LED. This provides the user with a mechanical alignment tolerance as well as the average power intensity within the aperture. Figures 10A,10B, and 10C show information from the T–1 3/4 data sheet.

Figure 10A. Outline Drawing from OP293/298 GaAlAs Data Sheet



DIMENSIONS ARE IN INCHES (MILLIMETERS)

Figure 10B. Beam Pattern of OP293

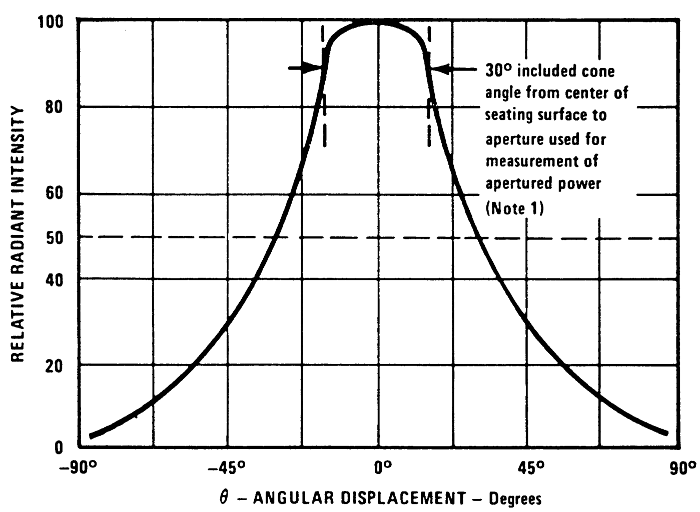
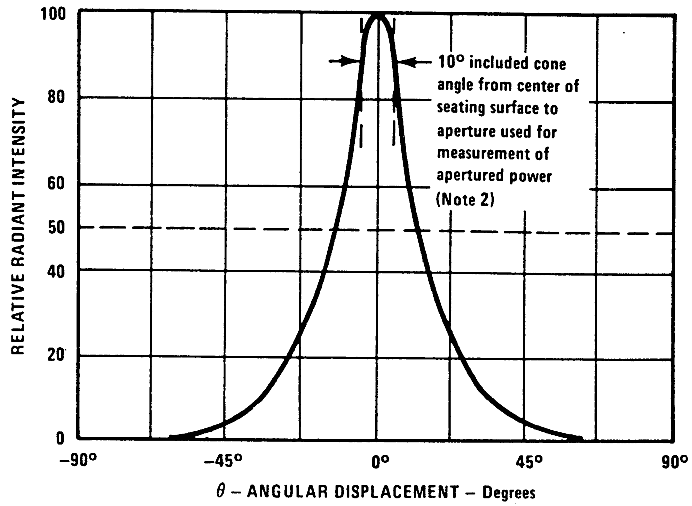


Figure 10C. Beam Pattern of OP298



Notes to Figures 10A, 10B, and 10C:

(1) $E_{e(APT)}$ is a measurement of the average apertured radiant energy incident upon a sensing area 0.250" (6.35 mm) in diameter perpendicular to and centered on the mechanical axis of the lens and 0.500" (1.27 mm) from the measurement surface. $E_{e(APT)}$ is not necessarily uniform within the measured area.

(2) $E_{e(APT)}$ is a measurement of the average apertured radiant energy incident upon a sensing area 0.250" (6.35 mm) in diameter perpendicular to and centered on the mechanical axis of the lens and 1.429" (36.30 mm) from the measurement surface. $E_{e(APT)}$ is not necessarily uniform within the measured area.

Conclusion

Power measurement of LEDs varies more than any other parameter between different manufacturers. Part of the difference is in interpretation of the definitions of the parameters measured and part is the technique used. Users should be able to predict how devices will work in their application by using data sheet information, and this bulletin should be useful to that end.

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