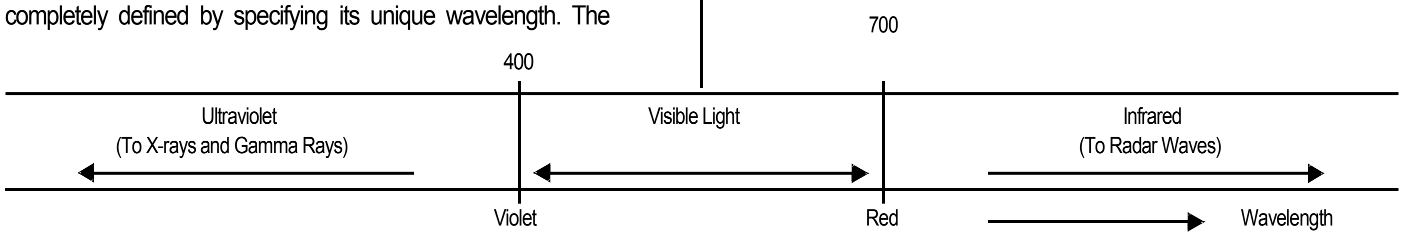
Application Notes—Photoconductive Cells

APPLICATION NOTE #1
Light - Some Physical Basics

Light is produced by the release of energy from the atoms of a material when they are excited by heat, chemical reaction or other means. Light travels through space in the form of an electromagnetic wave.

A consequence of this wave-like nature is that each "color" can be completely defined by specifying its unique wavelength. The wavelength is defined as the distance a wave travels in one cycle. Since the wavelengths of light are very short they are normally measured in nanometers, one nanometer being equal to 1×10^{-9} meters.

The spectral response of Excelitas' photoconductors are specified by lots of relative response versus wavelength (color) for various material types.



Violet	Below 450 nm
Blue	450 - 500 nm
Green	500 - 570 nm
Yellow	570 - 590 nm
Orange	590 - 610 nm
Red	610 - 700 nm

Natural Illuminance

Sky Condition	Light Level (Typical)
Direct Sunlight	10000 fc
Overcast Day	1000 fc
Twilight	1 fc
Full Moon	0.1 fc
Clear Night Sky (moonless)	0.001 fc

Room Illumination

Lighting Condition	Light Level (Typical)
Candle - Lit Room	5 fc
Auditorium	10 fc
Classroom	30 fc
Inspection Station	250 fc
Hospital Operating Room	500 - 1000 fc

APPLICATION NOTE #2

Light Resistance Measurement Techniques

The light resistance or "on" resistance (RON) of a photoconductor cell is defined as the resistance of the cell as measured at a special light level using a light source with a known output spectrum. Furthermore, the cell must be "light adapted" for a specific period of time at an established level of illumination in order to achieve repeatable results.

The industry standard light source used for light resistance measurements is a tungsten filament lamp operating at a color temperature of 2850 K. Specifying the 2850 K color temperature for the light source fixes the spectral output (i.e. the tungsten filament light has fixed amounts of blue, green, red, and infrared light).

For consistency and ease of comparing different cells, Excelitas lists light resistance values for its photocells at two standard light levels: 2 fc (footcandles) and at 10 lux. The footcandle is the old, historical unit for measuring light intensity and is defined as the illumination produced when the light from one standard candle falls normally on a surface at a distance of one foot. The lux (the metric unit of light measurement) is the illumination produced when the light from one candle falls normally on a surface of one meter. The conversion between footcandle and lux. is as follows:

1.0 fc = 10.76 lux
1.0 lux = 0.093 fc

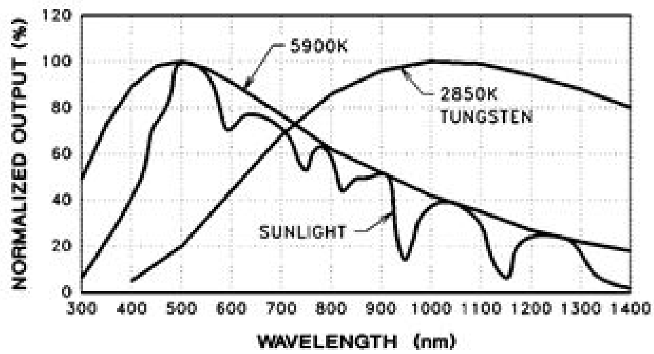
As explained in the section on "Selecting a Photocell", the "light history" effect necessitates the pre-conditioning of the cell before a light resistance measurement is made. Excelitas stores all cells at room temperature for 16 hours minimum at 30 - 50 fc (about 320 - 540 lux) prior to making the test measurement.

Sometimes the design engineer or user does not have access to the precision measurement equipment necessary to determine the light levels or light intensities of the application. Should this prove to be a problem, calibrated photocell samples with individual data can be provided by Excelitas.

APPLICATION NOTE #3

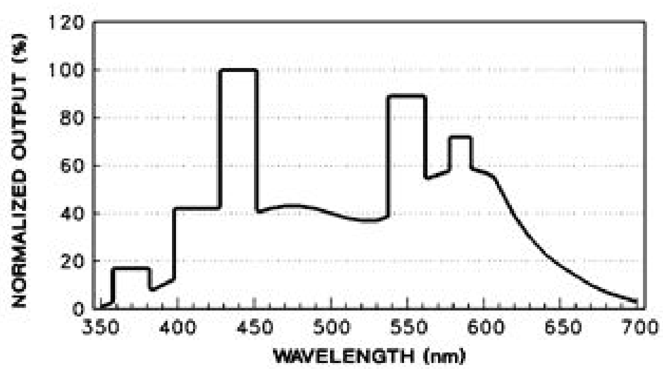
Spectral Output of Common Light Sources

Incandescent lamps can be considered as black body radiators whose spectral output is dependent on their color temperature. The sun has approximately the same spectral radiation distribution as that of a black body @ 5900 K. However, as viewed from the surface of the earth, the sun's spectrum contains H_2O and CO_2 absorption bands.



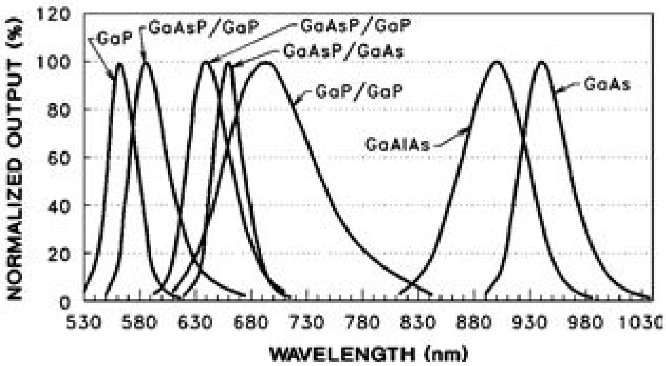
Black Body Sources Output vs. Wavelength

Fluorescent lamps exhibit a broad band spectral output with narrow peaks in certain parts of the spectrum. Shown below is a plot of the light output of a typical daylight type fluorescent tube.



Fluorescent Lamp Output vs. Wavelength

Due to their long operating lifetimes, small size, low power consumption, and the fact they generate little heat, LEDs are the light sources of choice in many applications. When biased in the forward direction LEDs emit light that is very narrow in spectral bandwidth (light of one color). The "color" of the light emitted depends on which semiconductor material was used for the LED.



LED Light Sources

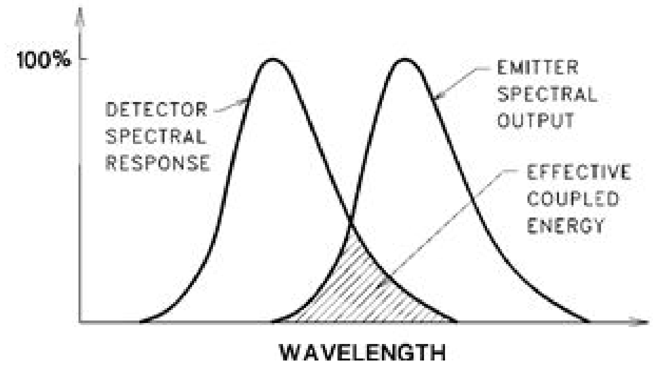
LED Type	Color	λP
GaP	GREEN	569 nm
GaAsP/GaP	YELLOW	585 nm
GaAsP/GaP	ORANGE	635 nm
GaAsP/GaAs	RED	655 nm
AlGaAs	RED	660 nm
GaP/GaP	RED	697 nm
GaAlAs	INFRARED	880 nm
GaAs	INFRARED	940 nm

APPLICATION NOTE #4
Spectral Matching of LEDs and Photoconductive Types

Since light sources and light detectors are almost always used together the designer must take into consideration the optical coupling of this system or the ability of the detector to "see" the light source.

In order to have good optical coupling between the emitter and the conductor the spectral output of the light source must, to some degree, overlap the spectral response of the detector. If the design involves the use of a light source with a broad band spectral output the designer is assured that the photocell will have good response to the light. This may not be the case when an LED light source is employed. LEDs emit their light within a very narrow spectral band so that they are often considered to be emitting at only on (peak) wavelength.

Spectral matching factors were calculated for a number of different LEDs and the photoconductor material types manufactured by Excelitas. Each matching factor was derived by multiplying the detector response curves by the LED spectral output curve and then measuring the resulting area.



The LED/photocell matching factors listed are independent of power output from the LEDs. In order to get a real feel on how well any LED/ photocell pair couple together, the power output from the LED at a particular forward drive current must be considered.

Normalized LED/Photocell Matching

LED Type	λP (nm)	Type Ø Material	Type 3 Material
GaP	569	39%	40%
GaAsP/GaP	58	60%	52%
GaAsP/GaP	635	49%	38%
GaAsP/GaAs	655	31%	27%
AlGaAs	66	31%	27%
GaP/GaP	697	47%	31%
GaAlAs	880	—	—
GaAs	940	—	—

The intensity of the light being emitted by visible LEDs is often given in units of millicandela. Millicandela is photometric unit of measure which assumes the human eye as the detector. For most detectors other than the human eye the most convenient system for measurement is the radiometric system. Listed below is the typical light power output of some LEDs measured at two different forward drive currents. Note that LEDs of a given type can show a 5:1 manufacturing spread in power outputs.

LED Type	Color	λP (nm)	Power Output	
			I_f = 1 mA	I_f = 10 mA
GaP	GREEN	569 nm	1.2 µW	24.1 µW
GaAsP/GaP	YELLOW	585 nm	0.3 µW	26.2 µW
GaAsP/GaP	ORANGE	635 nm	3.2 µW	101.9 µW
GaAsP/GaAs	RED	655 nm	6.2 µW	102.1 µW
AlGaAs	RED	660 nm	33.8 µW	445.1 µW
GaP/GaP	RED	697 nm	54.3 µW	296.2 µW
GaAlAs	INFRARED	880 nm	76.8 µW	1512.3 µW
GaAs	INFRARED	940 nm	35.5 µW	675.0 µW

Factoring in the power outputs of the LEDs, in this case at a forward drive current of 10 ma, coupling factors (matching factor multiplied by power output) for the various LED/material type combinations can be generated.

Normalized LED/Photocell Coupling Factors @ 10 mA

LED Type	λP (nm)	Type Ø	Type 3
GaP	569	3%	3%
GaAsP/GaP	58	5%	5%
GaAsP/GaP	635	17%	13%
GaAsP/GaAs	655	11%	9%
AlGaAs	66	47%	35%
GaP/GaP	697	47%	31%
GaAlAs	880	—	—
GaAs	940	—	—

Once gain, this data is intended as a general guide. LED power outputs can vary 5:1 between manufacturer lots.

APPLICATION NOTE #5
Assembly Precautions

When soldering the cell leads take all measures possible to limit the amount of heating to the photocell. The maximum recommended soldering temperature is 250°C with a solder duration of 5 seconds. Heat sink the LEDs if possible. Keep soldering iron 1/16 inch (1.6 mm) minimum from base of package when soldering.

Avoid chemicals which can cause metal corrosion. Do not clean the plastic coated cells with organic solvents (ketone types). Check with factory for specific cleaning recommendations.

Finally refrain from storing the cells under high temperature and/or humidity conditions. If cells are stored in the dark for any length of time please "light adept" before testing (see section on Light History Effect). Storage in the dark will change both the sensitivity and decay time of the cell.

APPLICATION NOTE #6
A Low Cost Light Source for Measuring Photocells

The Light Source used in the measurement of photocell resistance must be characterized for intensity and spectral composition. Excelitas uses a tungsten filament lamp having a spectral output approximating a black body @ 2850 K with a known candlepower output at a specified voltage and current.

While calibrated lamps of this type are available from the National Institute of Standards and Technology (formerly NBS) and private testing labs, a low cost alternative is to use a 100 W, inside frosted, tungsten filament lamp available from any home or hardware store. Such a lamp operated at 120 VAC will produce approximately 90 candlepower (cp) of illumination and a color temperature of 2700 K to 2800 K.

The relationship between candlepower and footcandle is:

$$\text{footcandle} = \frac{\text{candle power}}{(\text{distance in feet})^2}$$

Since this equation assumes a point source of light, the distance between lamp and detector should be at least five times the lamp diameter.

There are some characteristics of incandescent lamps which should be noted:

1. Color temperature increases with increasing wattage.
2. When operated at a constant current, light output rises with time.
3. When operated at a constant voltage, light decreases with time, especially during the first few hours.

APPLICATION NOTE #7
How to Specify a Low Cost Photocell

Sometimes the demands of the application such as power dissipation, “on” resistance, voltage, temperature coefficient, etc. limit the selection of the photocell to one particular device. However, more common is the case where any number of photocell types can be used, especially if minor changes are undertaken at an early enough point in the circuit design. In these cases, price is often the deciding factor.

Many factors influence price. In order to give some guidance and weight to these factors the reader is referred to the following table which is meant to serve as a general guide.

Lower Cost	Factor	Higher Cost
Plastic	**Packaging**	Glass/Metal
Broad	**Resistance Range**	Narrow
Small	**Package Size**	Large
Open Order with Scheduled Releases	**Scheduling**	Released Orders
Standard Tests	**Testing**	Special Tests