Carclo Optics
Guide to choosing secondary optics

Introduction

To quote from Pirelli's advertisement for tyre's, "Power is nothing without control" and equally the same analogy can be drawn with light. Seldom will the end user care about the total amount of light an LED radiates, rather what counts is where the light is going and how bright it is. Sending the light in the desired direction and obtaining the required brightness means controlling and directing the light output from the LED. (And it must not be forgotten that it is often just as important that light is kept away from other areas.) To do this usually requires more than just the pointing the LED's clear lens, (the primary optic), in the right direction. For the majority of applications producing the illumination in the required area and at the desired level requires additional or secondary optics. This guide aims to help in the selection of the best secondary optics and with the calculation of the illumination levels that will be achieved.

Information you need before you start

Although it sounds obvious, the first steps in selecting the best secondary optics for an application is to determine what illumination levels you want to achieve and over what area. Then from these two figures the total amount of light that will be needed can be calculated. Once you know how much light you need, it is then possible to decide what type of LED is required and how many. Only when the inputs to the optics, (the type and number of LED's), and the outputs, (the illumination level and beam shape), have been defined can the secondary optics be specified.

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Quantifying light output

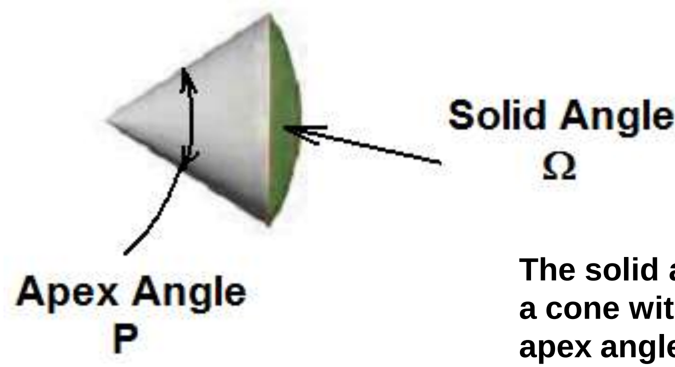
Often the first problem that someone new to lighting design has is defining the requirement in specific terms that can be used to calculate how much light is required. Carclo uses the metric system of light units for all our data sheets.

The metric unit of measurement for light seen by the human eye is called the lumen. The lumen is used to quantify the total amount of light radiated by a visible light source, in this case the LED. However what is important in most applications is how bright the light will be and this depends on what area the light is concentrated into.

To specify what illumination level is needed on a surface you need to calculate how much light is needed per square meter of surface. This unit of measurement is called Lux and is the amount of total light in lumens divided by the area being illuminated. Lux can be measured with a light meter.

If you need to specify the brightness of a light that is viewed at a significant distance, the unit of measurement to use is the candela. Candela is defined as the amount of light in lumens being radiated into each steradian of solid angle. (To calculate solid angle, imagine putting the light at the centre of a sphere with a radius of 1 meter. The amount of surface area in meters squared of the sphere that the light passes through is equivalent to the solid angle in steradians.)

The removed cone has an apex solid angle of 1 Steradian



The solid angle of a cone with an apex angle of Ω is given by:

$$\Omega = 2\pi\,(1 - \cos(P))$$

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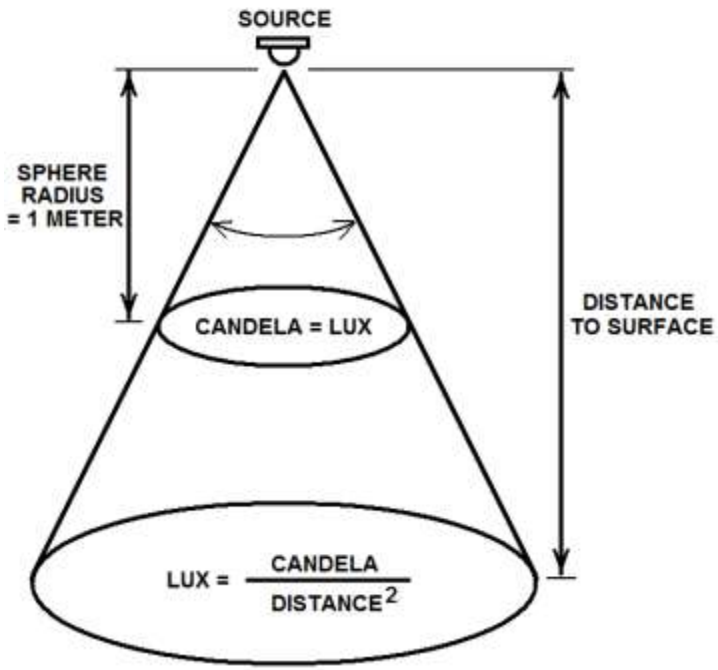
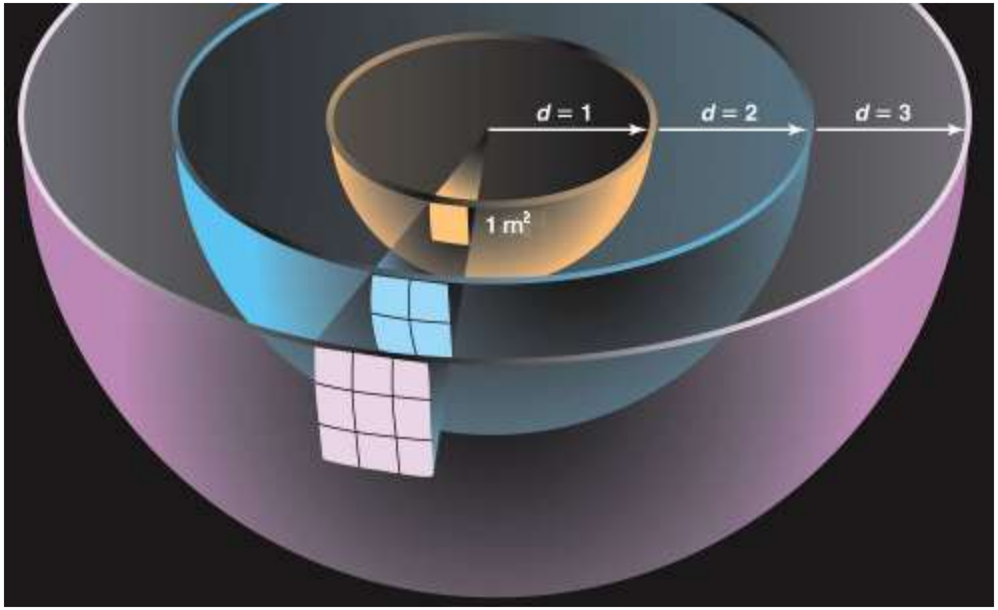
Converting from Candela to Lux

To convert from Candela values to Lux: Divide the Candela values by the square of the distance in meters from the light source to your illuminated surface.

Converting from Lux to Candela.

To convert from Lux to Candela: Multiply the Lux values by the square of the distance in meters from the light source to your illuminated surface.





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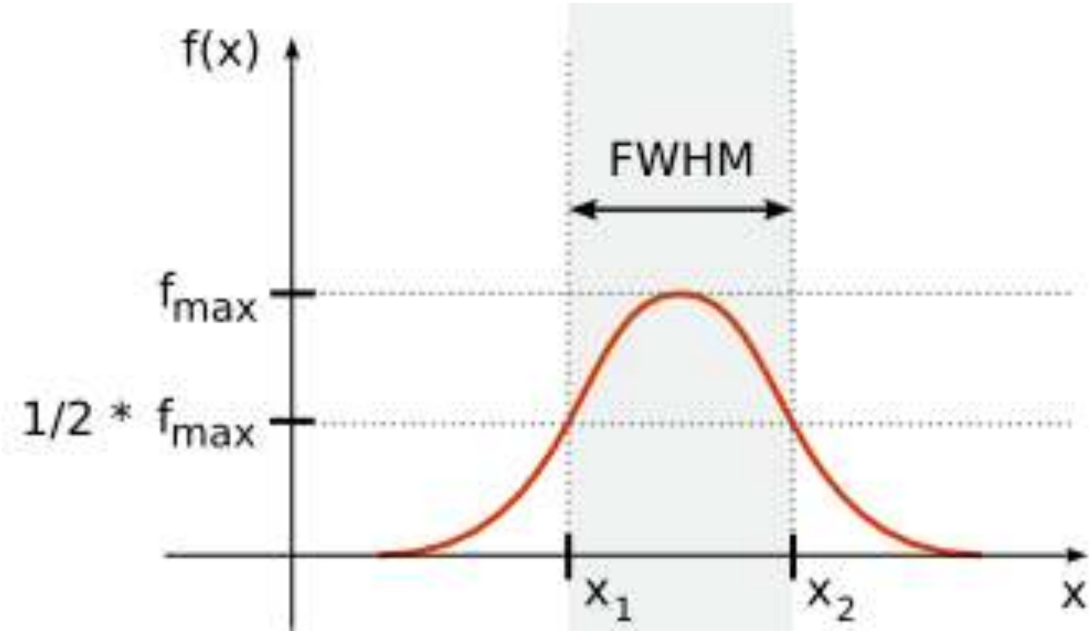
Specifying the beam width

It is impossible to produce a perfect beam of light that does not spread out. The finite size of the emitting region of the LED source means that the light will diverge. How much the light spreads out depends on the emitting area of the LED chip and the type of secondary optics that are used. For this reason the beam widths that a secondary optic produces have been measured with each LED type that it can be used with

Secondary optics are characterised by how wide a beam they produce. The beam width is quoted as an angular width rather than a physical beam size at a given distance. The angular width the optics produce is usually specified by measuring the angular separation between the directions, (x_1 and x_2) at which the intensity has fallen to half its peak value, (f_{max}). This value is called the Full Width Half Maximum (FWHM) divergence.

It is important to note that it is ***not*** possible to calculate from the FWHM beam width how big the beam will look to the human eye. The visible size will depend on other factors such as the ambient lighting conditions and the colour LED that is being used. In very low ambient lighting conditions the beam will look far larger than the FWHM size because the observer looking at the spot of light can see clearly the very faint edges of the distribution. Against a bright background the beam size will look much more like the spot size that would be calculated from the FWHM angular width.



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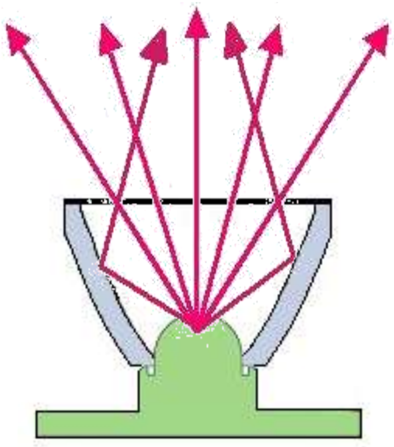
Selecting Secondary Optics

The type of optics that will best suit an application are mainly determined by the beam width of the illumination that you want to produce. The type of LED selected as the light source will also effect the choice of optic. At the present time there is no industry standard package for high power LED's, different manufacturers have used different encapsulation techniques. Because of this some of Carclo's range of optics have variants particularly optimised for certain LED types.

Reflectors

To produce very wide beams, (up to 80 degrees FWHM) a reflector is the best choice. Reflectors have good efficiency and have a very sharp beam edge. The Carclo 80 degree reflector produces a very even circle of light and is ideally suited for applications such as the luminaries used on petrol station forecourts.



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TIR Optics

To produce smooth circular beams with FWHM angular widths between 12 and 35 degrees a Total Internal Reflecting (TIR) optic is the optimum solution. To produce elliptical beams the TIR optics are available with a linear ripple surface that generates an even intensity line. The classic 20mm diameter range of TIR optics are available for a wide range of LED types.

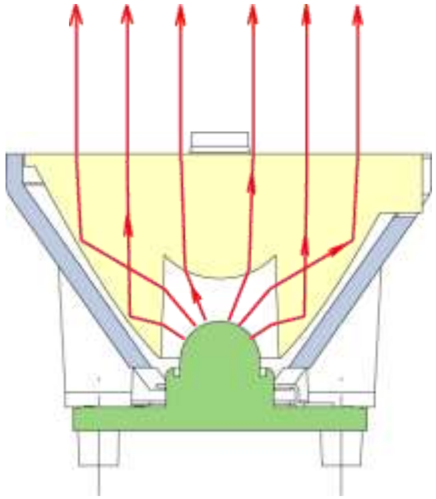
By using a proprietary frosted surface on the front of the optics Carclo are able to vary the angular beam width while maintaining a smooth profile without compromising the optical efficiency.

Elliptical beams are created through the use of linear ripple profiles moulded on the top surface of the TIR optics.

A range of larger 26.5mm diameter TIR optics is designed to produce narrow divergence output beams.

Manufactured in lens quality polycarbonate, Carclo's TIR optics have much higher temperature resistance than acrylic optics, (up to 125°C compared with 95°C) and carry a UL rating. These one piece optics are tough and impact resistant but precautions should be taken to prevent them from coming in to contact with organic solvents or vapour.

Diagram showing light ray paths through a TIR optic



Picture showing Carclo 20mm diameter frosted optics

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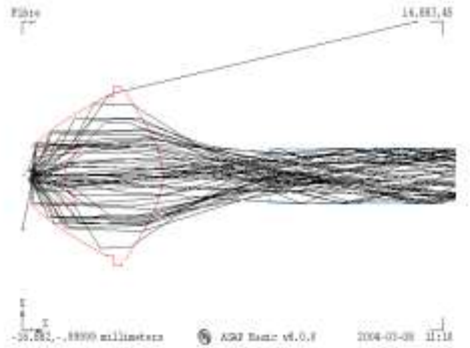
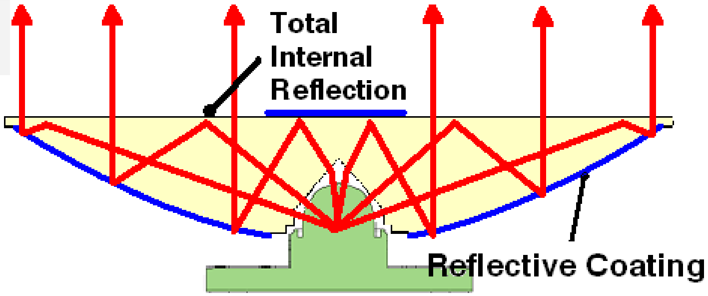
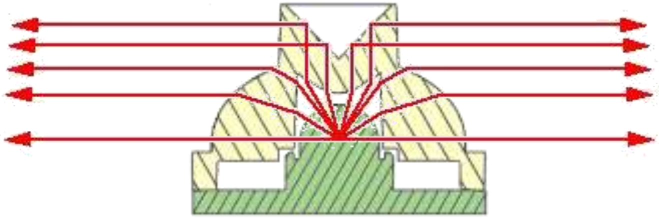


Specialist Optics

To focus the light from an LED on to the end of a fibre bundle Carclo manufacture a standard 20mm diameter lens with an integrated focusing lens. Optimised for NA 0.5 fibre bundles with diameters of between 8 - 12mm this optic can be used to make compact microscope illumination systems.



To produce the narrowest of beams Carclo manufacture catadioptric reflector optics. These are available in 50mm and 60mm diameters. The ability to create very tight beams with FWHM divergence as small as 3 degrees makes them ideally suited to applications such as beacons and spot lights.



To create a narrow beam of light that covers 360 degrees around the LED Carclo manufacture side emitter optics for a number of LED's. These are ideally suited to a wide range of applications such as beacons and runway lighting. They also have applications in large area backlighting where they can be used to couple light in to standard 10mm thick PMMA or Polycarbonate sheets.

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Holders for LED Optics

When mounting secondary optics it should be remembered that positioning the optics at the correct height relative to the LED is essential if you are to obtain the best efficiency and the correct beam width. Equally important is the alignment of the optic axis to the LED chip. If not correctly positioned the output beam will become uneven and offset. The axial placement accuracy required is dependent on the beam width of the optic. Generally the wider the beam divergence of the optic the more tolerant it will be of axial displacement. As a general guide, an accuracy of +/-0.2 mm is required for the optics that produce the narrowest beams, although for the widest beams this can be relaxed to +/-0.4mm.

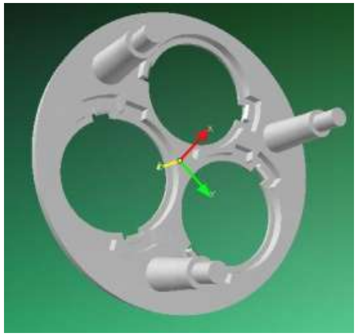
To help users mount their optics at the correct focus height and to correctly align them to the LED chip Carclo supply a range of optic holders that mount on the PCB and locate the optics to the LED base.

All optical plastics can be damaged by organic solvents. In particular the optical surfaces can fog if exposed to organic solvent vapour. It is therefore very important that only low vapour adhesives are used for gluing holders to circuit boards.

Standard circular holders are for mounting both the 20mm and 26.5mm diameter to a wide range of LED types.

Many LED's are now available ready mounted on hexagonal 'starboard' style PCB's. Carclo has a range 'starboard' specific holders for many LED types.

Holders are available for mounting optics as triples in the standard 50mm diameter 'MR16' style fittings.



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