XLamp® Horizon LED Design Guide

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INTRODUCTION

Cree LED has expanded its horticulture XLamp® LED portfolio with the XLamp Horizon LEDs, new beam shapes designed to spread the LED's light output more evenly over the plants below. Through efficient design and free-form silicone encapsulants designed to produce a wide distribution, XLamp Horizon LEDs can be placed up to 40% closer to plant beds than LEDs with standard dome shapes, while also providing up to 10% greater light levels and similar uniformity. By taking advantage of the new beam shapes, shelving space in vertical farms can be maximized or light uniformity and efficiency in greenhouses can be improved.

This design guide details the optical characteristics of the XLamp Horizon LEDs and documents a lighting study that shows how these new LEDs can impact horticulture lighting design.

Optical Advantage

As a light source, LEDs have an advantage over other light sources as they are directional, emitting light in to predominantly a hemisphere rather than a full sphere as do traditional sources.

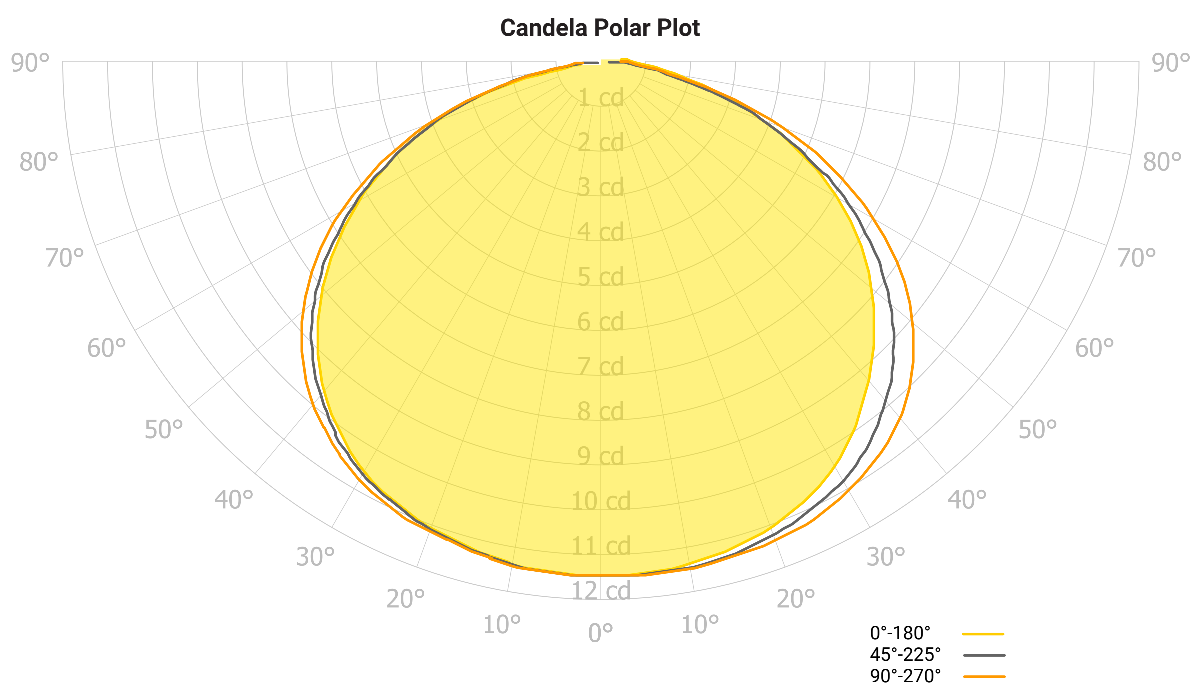

Figure 1: Standard XP-G3 Photo Red LED polar plot

While this is an advantage outright, the light distribution from a standard XP-G3 LED may not be optimal for every application. In the case of vertical farming for horticulture applications, it is advantageous to maximize the number of shelves within a rack to maximize output. The distance required to adequately light a bed of plants becomes important. The closer a light source can be to the plant bed, the less space is required for a shelf. In such a case, a wide distribution is desired to create a more uniform distribution of light for a given mounting height while also avoiding hot spots below the light source.

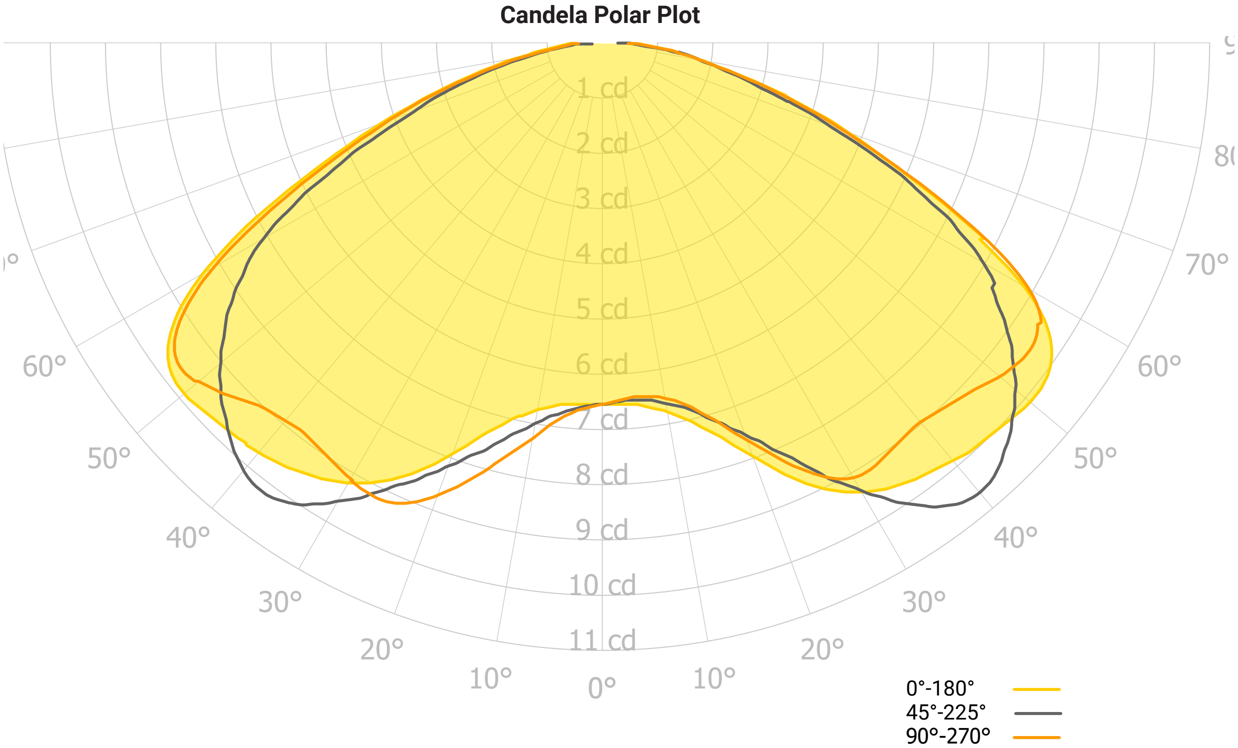

Figure 2: Horizon70 Photo Red LED polar plot

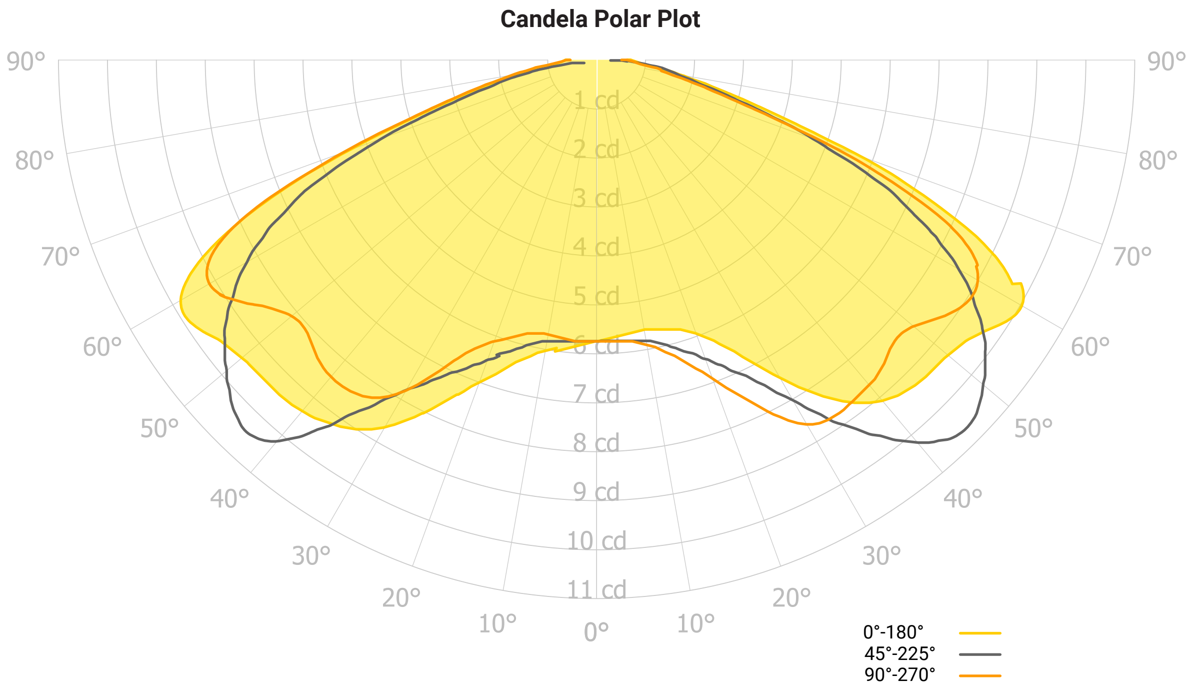

Figure 3: Horizon90 Photo Red LED polar plot

Generally, this is achieved by pairing a secondary optic with a standard XP-G3 LED. The optimal distribution for horticultural lighting can be generated by the LED directly by changing the shape of the silicone lens of the LED from a typical hemisphere to a shape similar to a toroid. This eliminates the need and expense for a secondary optic resulting in a more cost-efficient system.

OPTICAL TESTING

The Cree LED laboratory uses a near field goniophotometer from Radiant Vision Systems, SIG-400, to measure the distribution of LEDs in detail.

Methods

An IES file is generated by tracing 10,000,000 rays from the near field data used for polar plots, zonal lumen summaries, and illuminance uniformity studies.

Photometric Toolbox software is used to compare photometric data and calculate zonal lumens.

DIALux lighting design software is used to study the differences between different encapsulant lenses for a hypothetical application layout.

Polar Plot Comparisons

The polar plot comparisons below compare a photo red standard encapsulant lens (XP-G3 LED) to two different encapsulant lenses (Horizon70, Horizon90) designed to produce wide distributions.

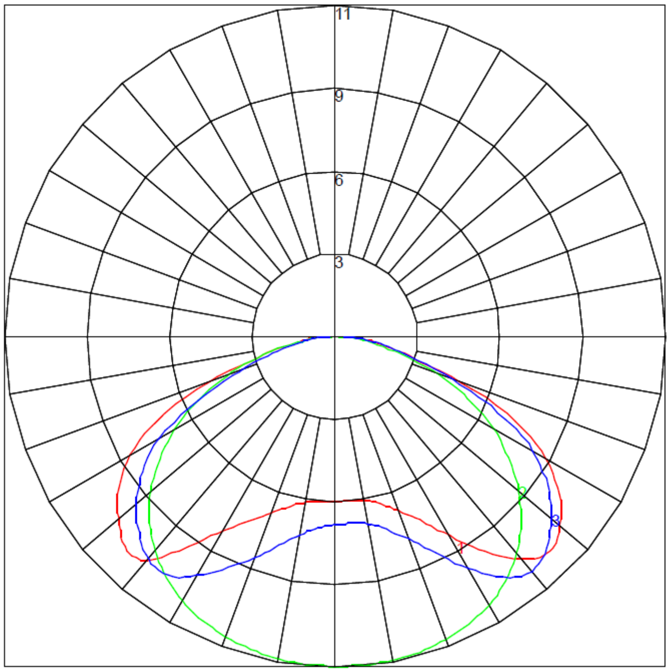

Figure 4: XP-G3 LED (green), Horizon70 (blue), Horizon90 (red) polar plots

Beam Spread

Beam spread, also called Full Width Half Maximum (FWHM) is a standard classification method for directional distributions like spotlights and floodlights. This system is consistent and predictable when the center of the beam, at nadir, is the maximum luminous intensity. When the maximum intensity is off axis from nadir, the FWHM value loses some meaning. The plot below shows how three very different distributions can have the same 130° FWHM value.

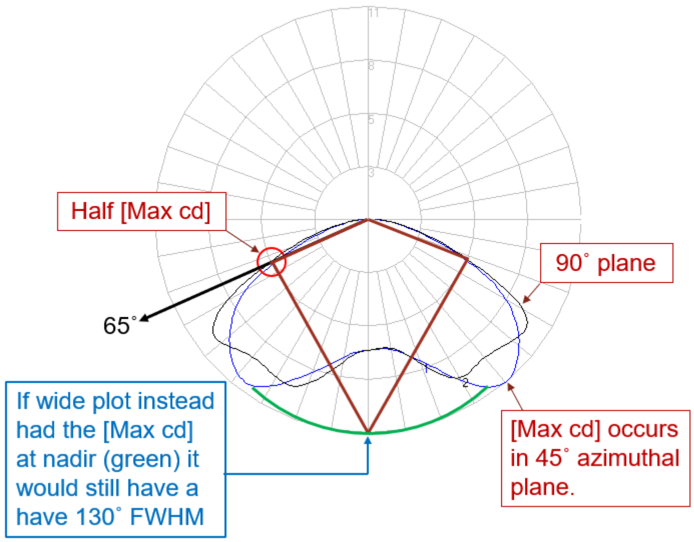

Figure 5: Polar plots showing that three radically different distributions can have the same 130° beam spread (FWHM). 1. Wide (thin blue), 2. Wide with additional flux 0-30° (thick green), and 3. Directional flood with peak at nadir (red)

For distributions with maximum intensity off-axis from nadir, like a wide distribution, FWHM loses its intended purpose for comparisons.

Spacing Criteria

There is another metric that considers the width of the distribution and the intensity at nadir. Spacing criteria (SC) is a metric developed as a shortcut for laying out indoor luminaires. Based on an IES distribution, this metric calculates a spacing to mounting height ratio required to make the illuminance directly below one luminaire the same illuminance as the point in between two or four luminaires, thus taking into account the flux directly below the fixture in conjunction with the width of the distribution and the overlapping distribution from an adjacent luminaire. A larger SC will allow greater spacing between luminaires. The table below shows how the beam distributions affect the spacing criteria.

Table 1: Spacing criteria for Horizon90, Horizon70, and XP-G3 photo red LEDs

Description	Horizon90 Photo Red	Horizon70 Photo Red	XP-G3 Photo Red
Luminaire Lumens	38	38	38
Spacing Criterion (0-180)	2.18	2.14	1.34
Spacing Criterion (90-270)	2.06	2	1.44
Spacing Criterion (Diagonal)	2.2	2.02	1.52

From the website of Lighting Analysts, makers of Photometric Toolbox:

"Spacing Criteria - An interior luminaire characteristic derived from the distribution of the direct component on the workplane. A luminaire's Spacing Criteria are an estimation of the spacing-to-mounting-height ratio(s) needed for a luminaire to produce uniform illuminance on a workplane, given a uniform luminaire array.

When considering the Spacing Criteria results, one should use the lowest value reported for all three cases."

Naming Convention

While Spacing Criteria is one metric that can be used to interpret the photometry, it is not intuitive with respect to a naming convention. Due to the inherent problem with beam spread, as discussed above, Cree LED have devised a different method of naming product using the vertical angle of the maximum luminous intensity and doubling that value (peak-to-peak angle). This is a more intuitive naming system without falling into the trap of the beam spread metric. In the case of Horizon90 below, the peak luminous intensity angle is 45°. The peak-to-peak angle is 90°.

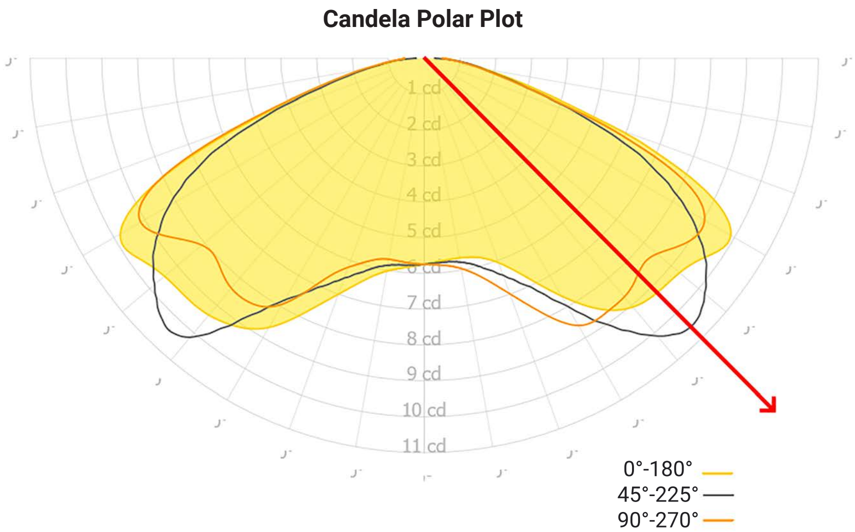

Figure 6: Horizon90 peak vertical angle

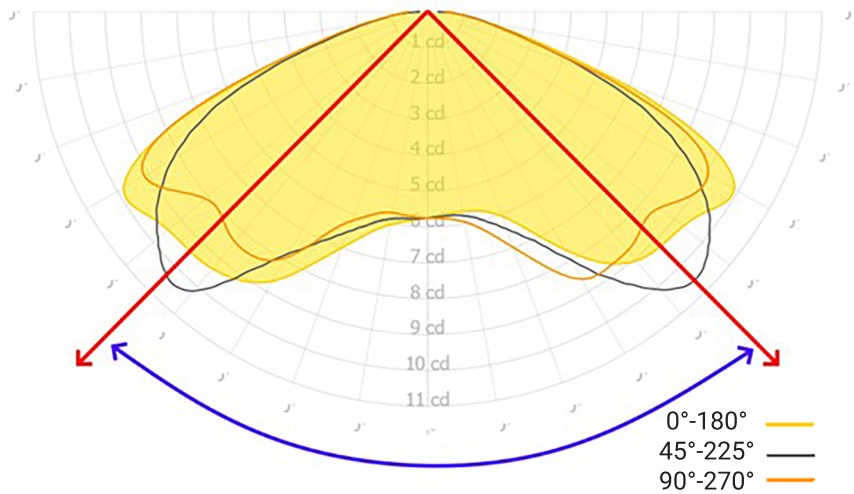

Figure 7: Horizon90 peak-to-peak angle

Zonal Lumen Summaries

The lumen summary of vertical angular bands is a good method of comparing different luminaire distributions. This method is sometimes used to compare interior luminaires and often used to compare exterior luminaires.

The Photo Red versions of the XP-G3, Horizon70 and Horizon90 LEDs illustrate how the zonal lumen values change with a variation in distribution.

Figure 8 shows the zonal lumens of Horizon lenses compared to standard.

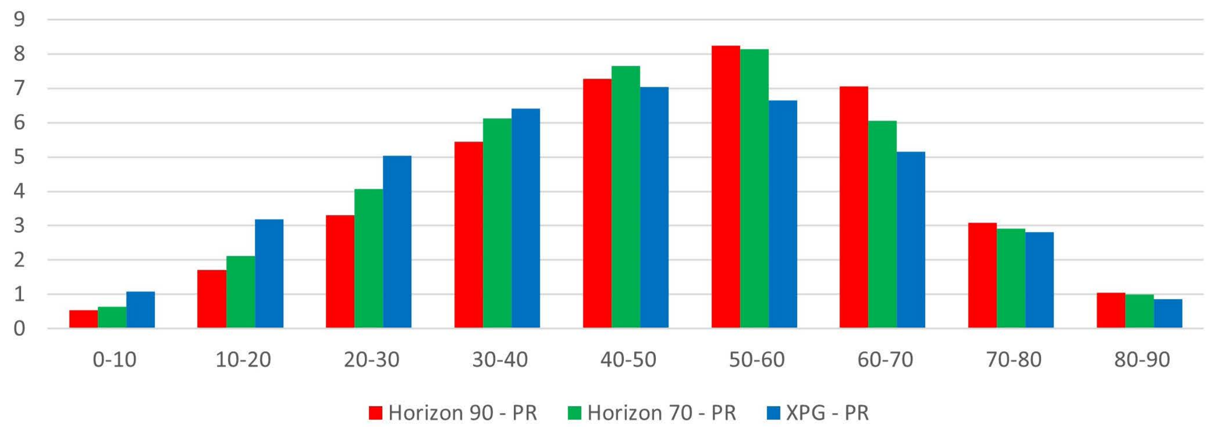

Figure 8: Zonal lumen graph of photo red Horizon90, Horizon70, and XP-G3 LEDs

While the photometry of different colors within a package configuration do not match perfectly, we can look at how flux is being distributed within vertical angular zones. Zonal lumens tend to illustrate how flux is distributed within a range of vertical angles and are a better predictor of how a complete system will behave.

The photo red, Photophyll™, and royal blue versions of Horizon90 illustrate the similarity of zonal lumens of the various colors.

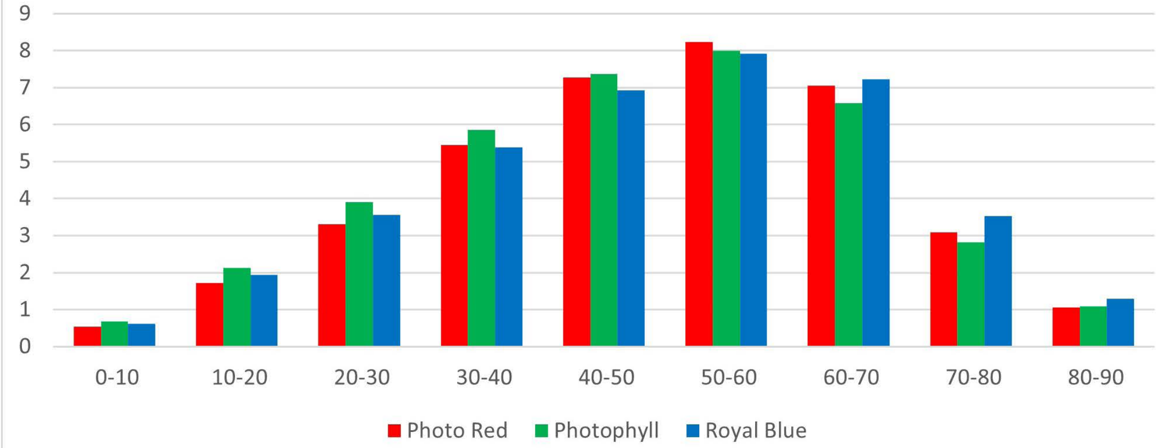

Figure 9: Zonal lumen graph of Horizon90 photo red, Photophyll and royal blue LEDs

From the website of Lighting Analysts, makers of Photometric Toolbox:

> ""Zonal lumens are computed by taking the average luminous intensity (candelas) at the center of the zone then multiplying by the zonal constant to arrive at the zonal lumen value. Photometric Toolbox uses the candela information and angles provided in the photometric file to calculate the average candlepower within each zone. Zonal lumens are computed by Photometric Toolbox for ten-degree zones then compiled to create a composite zonal lumen summary."

Illuminance Template – Square Pattern

As stated above, the maximum luminous intensity occurs in the 45° plane. This is advantageous as it produces a square illuminance pattern on the target plane. This pattern allows for good blending with adjacent LEDs and improves uniformity compared to a round pattern.

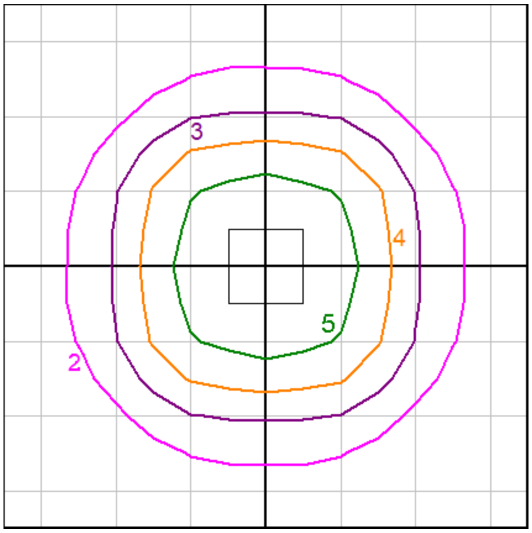

Figure 10: Illuminance contours in footcandles. Four Horizon90 LEDs, 2 ft above plane, 1 ft X 1 ft grid

APPLICATION ILLUMINANCE EXAMPLE

The illumination study simulates a single room divided by partition walls to isolate the different LED lens types. Illuminance is reported in footcandles rather than PPFD values as the uniformity calculations will be the same, regardless of the energy conversion metric utilized. While the room surfaces are assigned typical reflectance values (Ceiling 70%, Walls 50%, Floor 20%), the calculations are direct illuminance only and do not include interreflections from the room surfaces. (The room surfaces could be considered 0% reflective.) Surface reflectance better illustrates the room layout as an observer for rendered images only.

Lighting Layout for Illuminance Study

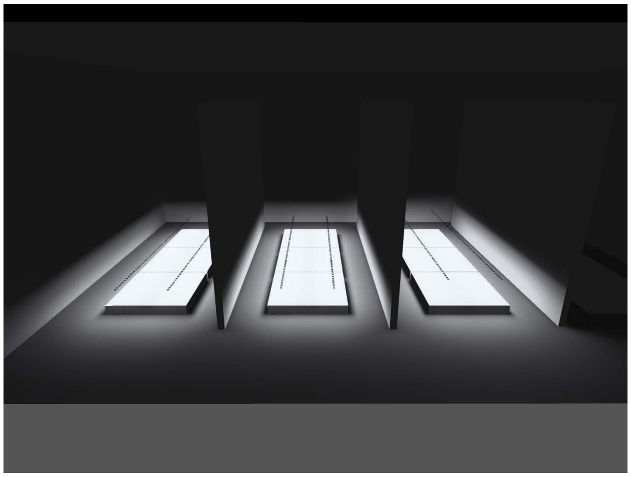

Figure 11: Room and partitions for illuminance study – rendered 3D view

In addition, the study considers only the LEDs and does not include a housing, reflector, or refractor that might be included in a typical luminaire assembly. The study is meant to illustrate the differences between the LED lenses and is not representative of a complete luminaire system. These limitations are an artificial construct and therefore represent worst-case scenarios. As part of a luminaire system, the results will be different.

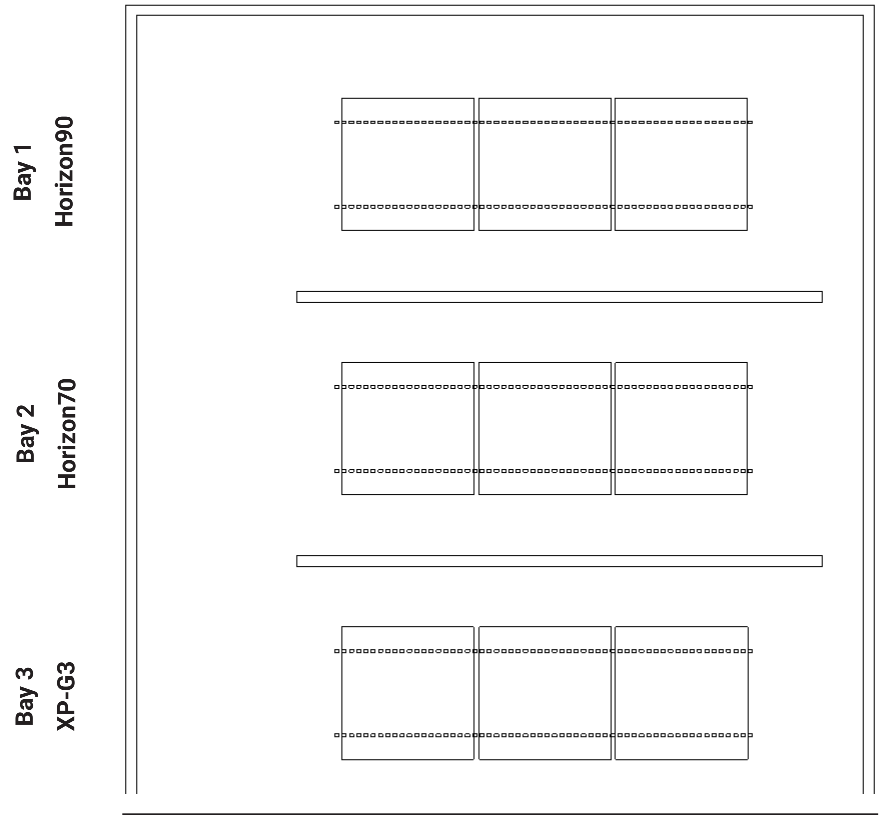

Figure 12: Illuminance study room layout - plan view

Mounting heights are defined from the top of the plant bed to the LED package luminaire light center.

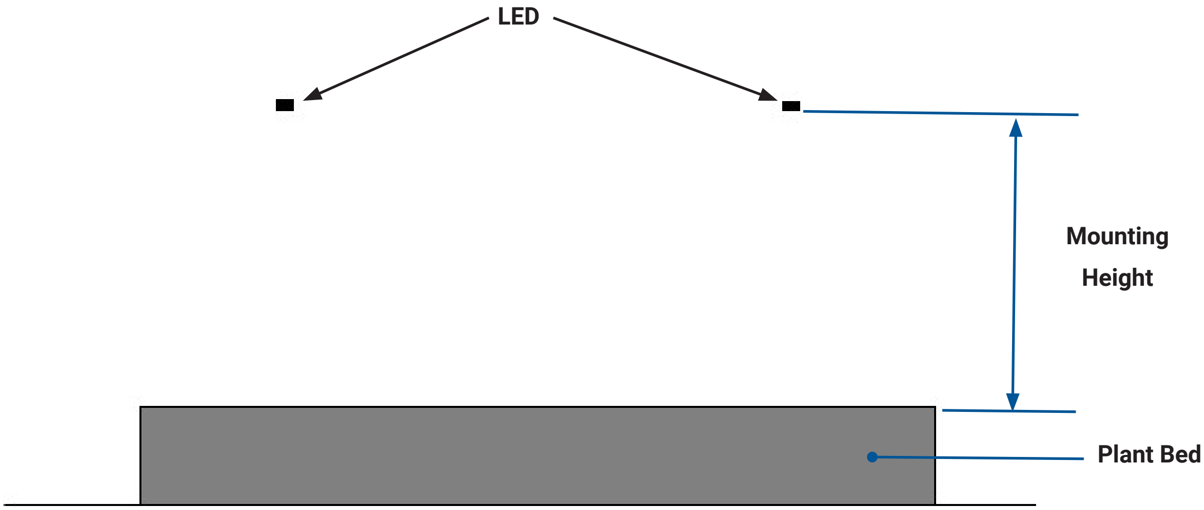

Figure 13: Elevation view: mounting height from top of plant bed

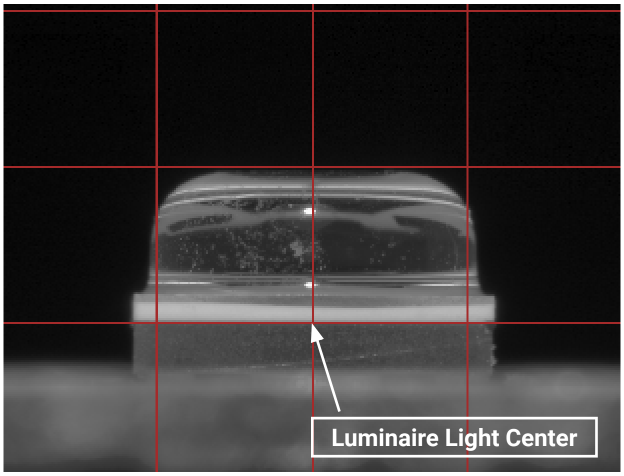

Figure 14: Horizon package luminaire light center

Illuminance Grid Layouts

Bed illuminance layout:

- Full length: 12 ft
- Width: 4 ft
- Middle length: 4 ft
- Illuminance points: 0.5 ft x 1 ft grid, includes outside edge of bed
- Luminaire spacing: 2.67 ft

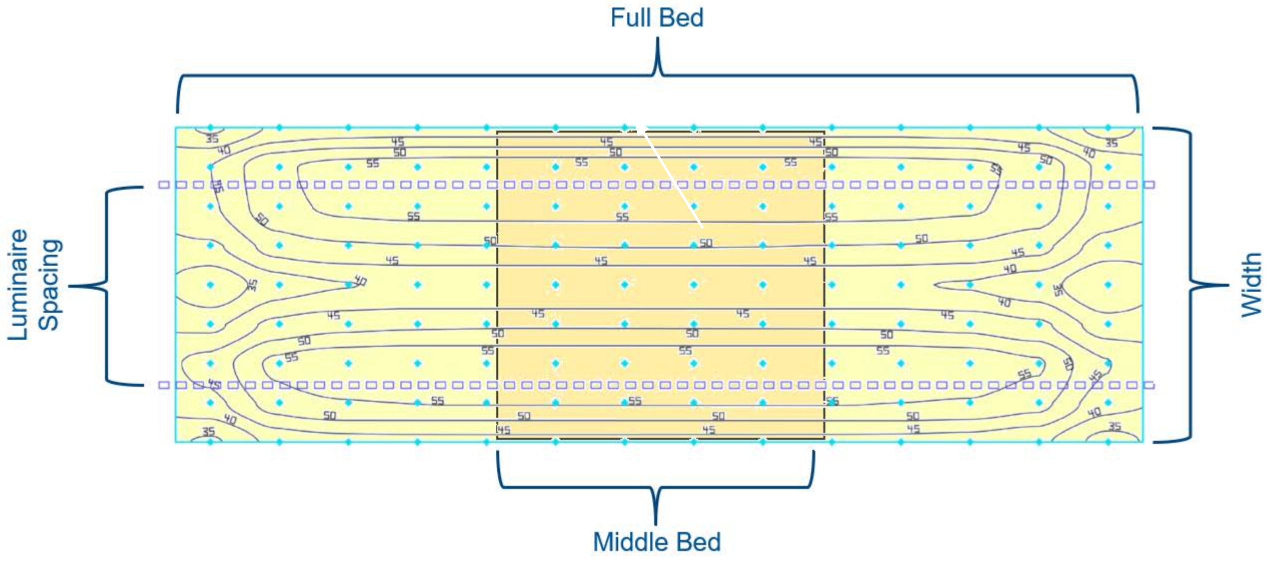

Figure 15: Illuminance grid layout, full and middle plant beds

Results

Illuminance and uniformity study parameters

- 4-ft bed – optimized layout
- All LEDs scaled to 38 lm
- Mounting height varies with encapsulant shape
- 2.6 ft luminaire spacing
- Middle 1/3 of bed:
    - >0.80 minimum/average uniformity

Full Bed

The full bed contours are shown below. Additional illumination at the ends of the beds, or end wall reflectors would be required for the full bed to meet the uniformity criteria.

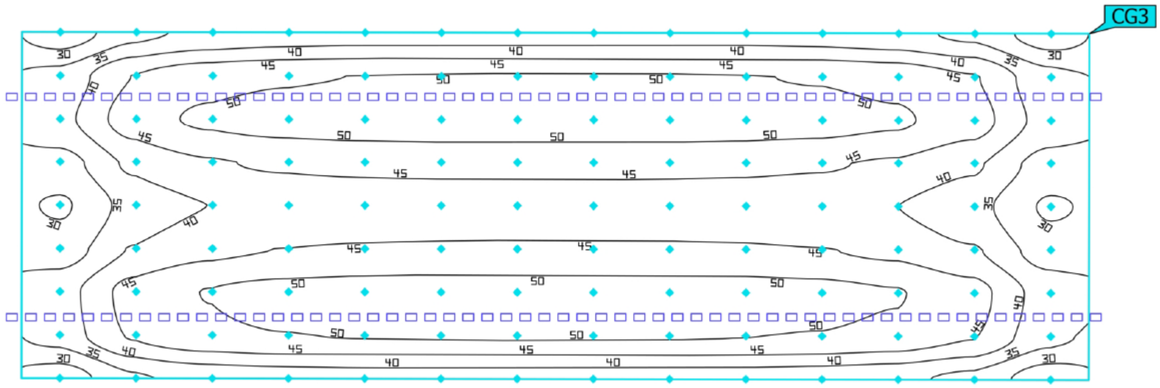

Figure 16: Illuminance contours – full bed, XP-G3 photo red LED

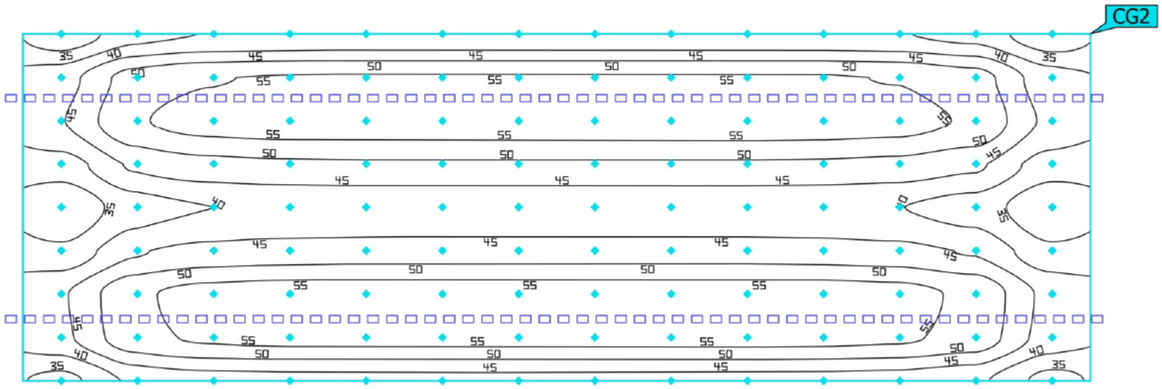

Figure 17: Illuminance contours – full bed, Horizon70 photo red LED

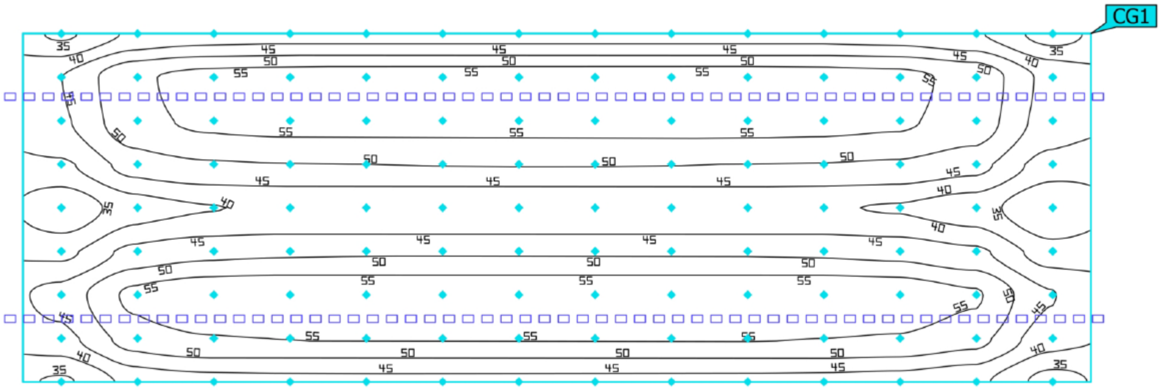

Figure 18: Illuminance contours – full bed, Horizon90 photo red LED

Middle Bed

The middle bed illuminance values are shown below

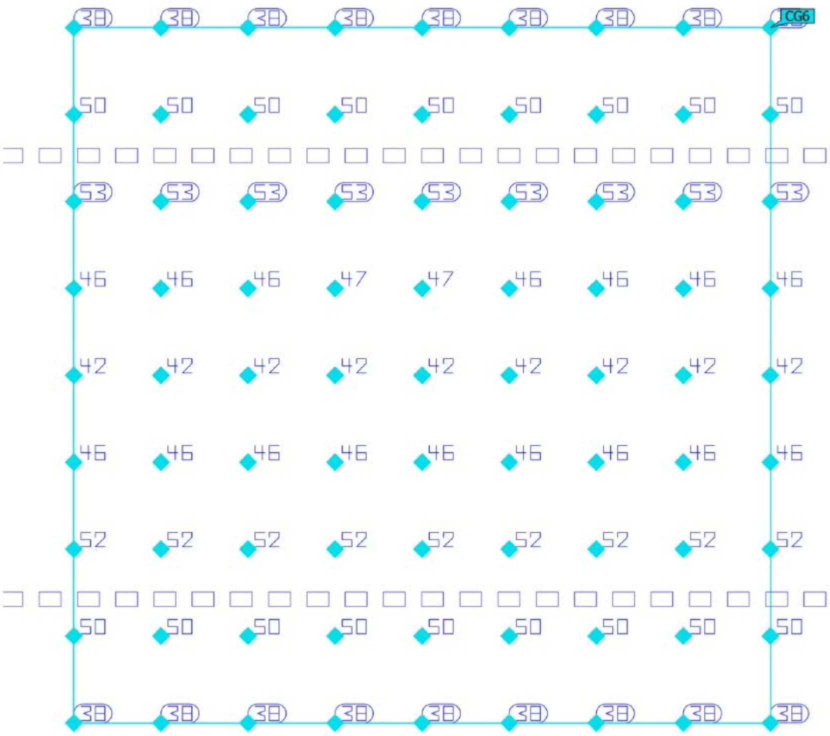

Figure 19: Illuminance values – middle bed, XP-G3 photo red LED

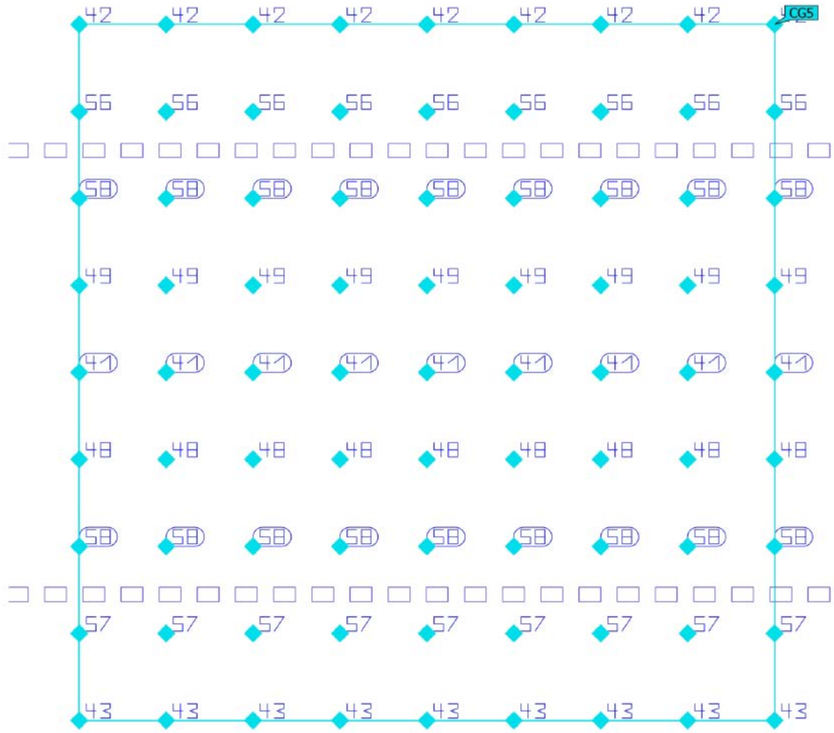

Figure 20: Illuminance values – middle bed, Horizon70 photo red LED

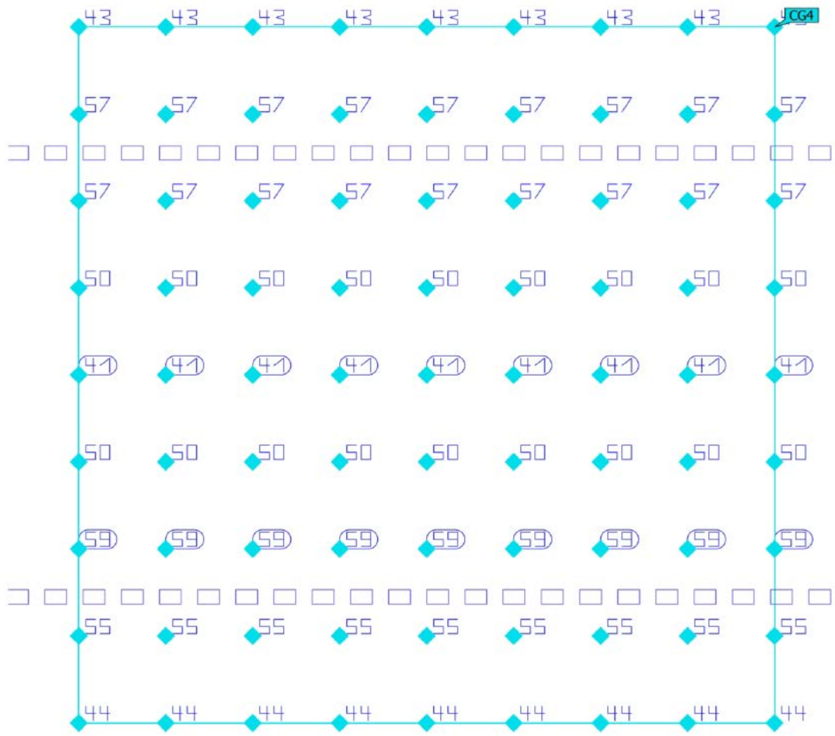

Figure 21: Illuminance values – middle bed, Horizon90 photo red LED

Table 2 illustrates the mounting heights required for a minimum/average uniformity greater than 0.80 of the middle section of the bed for the various encapsulant lenses.

Table 2: Illuminance and uniformity data for XP-G3, Horizon70, and Horizon90 LEDs

	XP-G3	Horizon70	Horizon90
	Photo Red	Photo Red	Photo Red
	Middle Bed	Middle Bed	Middle Bed
Mounting Height	1.5	1.1	0.9
Luminaire Spacing	2.6	2.6	2.6
Average	46	50	51
Minimum	38	41	41
Maximum	53	58	60
Minimum/Average	0.82	0.82	0.80
Minimum/Maximum	0.71	0.71	0.68

To achieve a minimum/average uniformity of 0.80, compared to a standard XP-G3 LED lens, the mounting height of the Horizon70 LED distribution can be reduced by 27% and the Horizon90 LED can be reduced by 40% to conserve valuable vertical space. Average illuminance is increased by 8% with the Horizon70 LED and 10% with the Horizon 90 LED.

In Table 3, for a set mounting height, the minimum/average uniformity for the Horizon90 encapsulant is shown for colors: photo red, Photophyll, and royal blue.

Table 3: Illuminance and uniformity data for Horizon90 photo red, Photophyll and royal blue LEDs

	Horizon90		
	Photo Red	Photophyll	Royal Blue
	Middle Bed	Middle Bed	Middle Bed
Mounting Height	1.1	1.1	1.1
Luminaire Spacing	2.6	2.6	2.6
Average	49	50	49
Minimum	43	41	40
Maximum	55	59	57
Minimum/Average	0.87	0.82	0.82
Minimum/Maximum	0.77	0.69	0.70

CONCLUSION

The XLamp Horizon LEDs show Cree LED's continued investment in innovation for horticulture lighting applications. These wider distributions reduce the vertical space required for proper illumination in vertical farming and can both increase flux onto the plant bed and greatly improve uniformity with a square illuminance pattern for greenhouses.

For more information about XLamp Horizon LEDs, please visit the Horticulture lighting application page or contact your Cree LED sales representative.