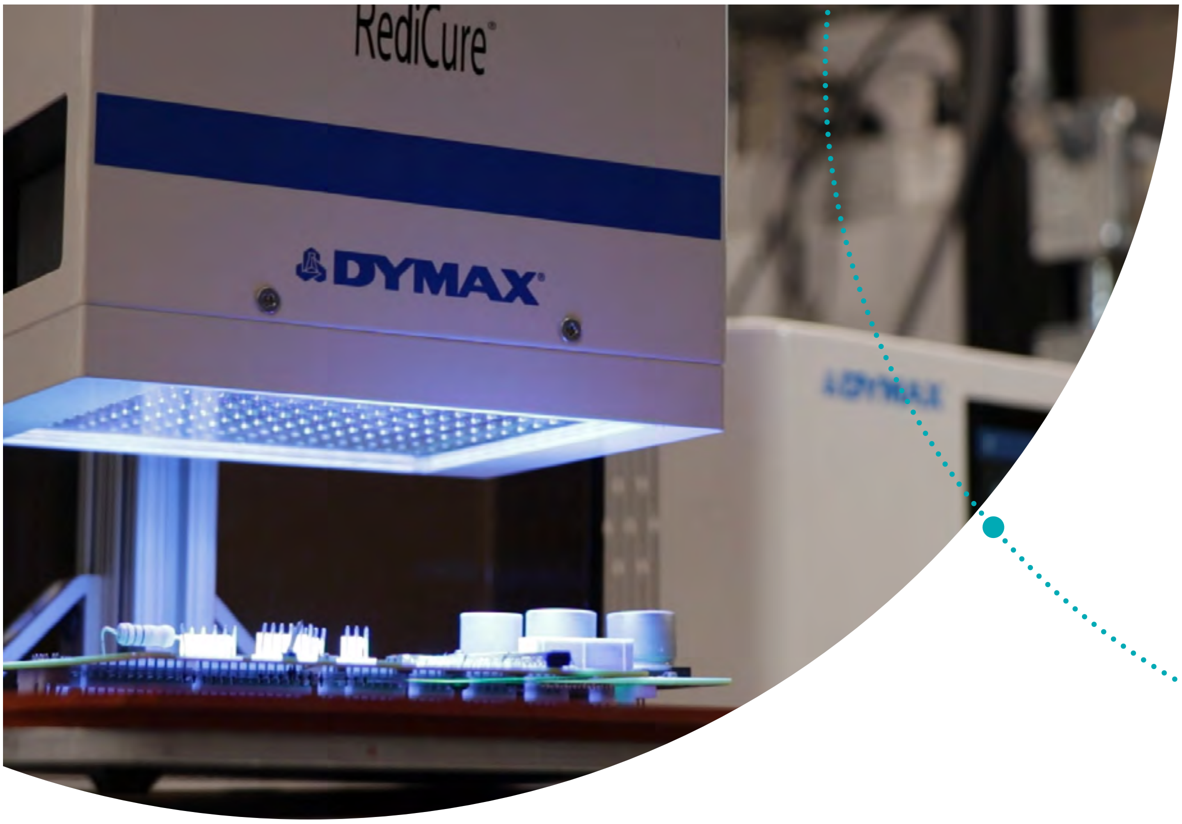

Comparison of Working Distance on Measured Intensity for LED Emitters

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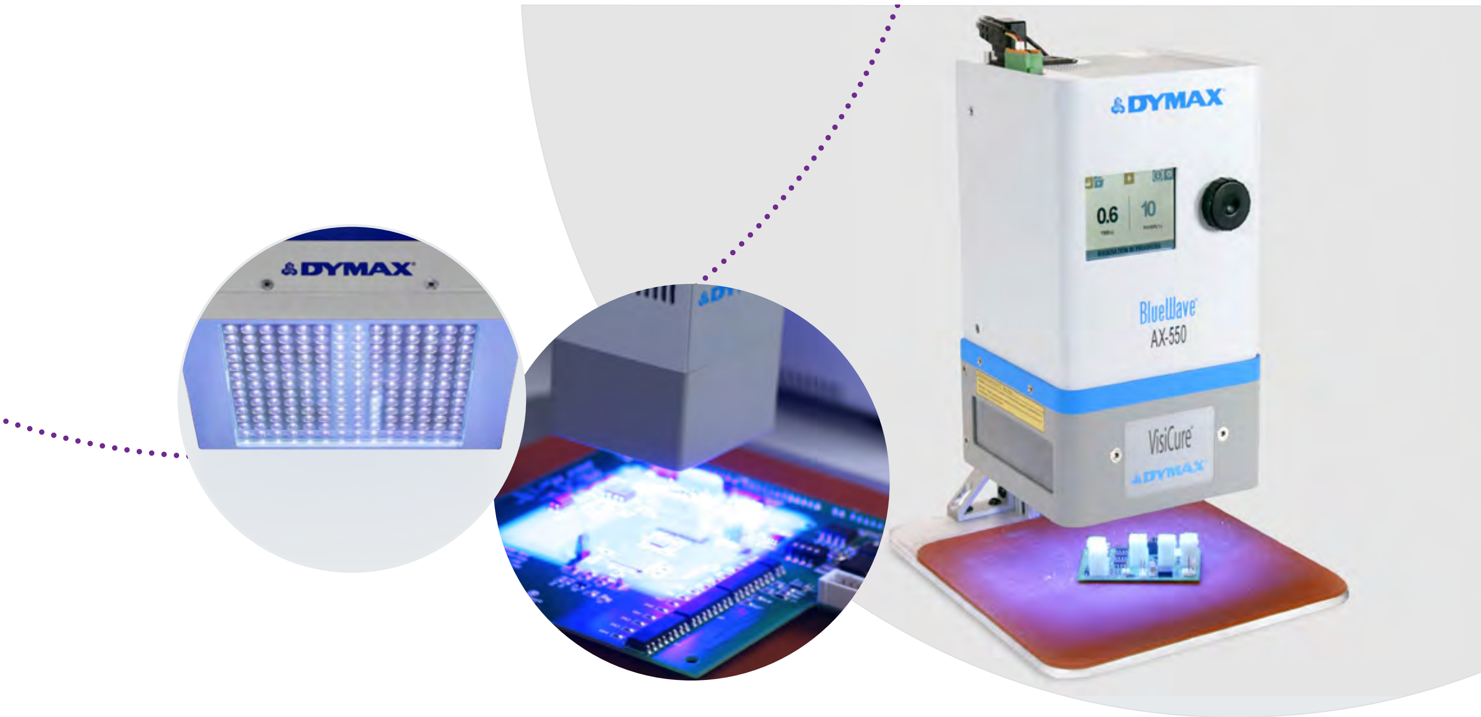


When selecting UV curing equipment, an engineer will often look at a product data sheet to review the specifications and compare two similar looking pieces. The engineer will compare the primary characteristics, such as intensity, curing area, and rated lifespan in combination with the price to make a comparison of the value.

Intensity is certainly an eye popper, and one of the important considerations when selecting a piece of UV curing equipment and using it to set up a process. The most common criterion for delivering a complete cure is the total dose of UV light, which is equal to the intensity delivered to the substrate times the duration of exposure.

*Total Dose = Intensity * Time*

Knowing the required dose, an engineer can use published intensity data to estimate the exposure time required by a given emitter. However, what's often overlooked is the distance at which that intensity is measured, and the distance at which the emitter is focused.

In a UV process, working distance is a very important consideration. Depending on the design of the light, intensity delivered to the substrate can vary considerably even among emitters with similar published peak intensity. The divergence and focus distance of the emitter can make a large difference in how the emitter performs as the distance changes.

Application matters. An emitter designed for an application like curing of printing inks, where the intention is to run the substrate at high speed, very close to the emitter face, the focus distance is not important. The emitter may not need to be focused at all. At 5-15 mm typical working distances, the performance at longer distances hardly matters. What is measured "at the glass" (at the array surface, 0 mm working distance, or what would be read if a measurement was taken right up against the emitter face) is essentially what is delivered. Contrarily, an emitter designed for adhesive applications, such as curing a conformal coating on a printed circuit board (PCB) needs to consider focus and working distance. The PCB may have components that extend several inches off the surface of the board. An unfocused lamp with high splay or divergence may no longer be effective in this type of setup.

When looking at data sheets, a process engineer will typically observe that there are large variances in the data provided by the manufacturer, and how that data is measured. Intensity is most frequently reported at the glass, and it's safe to assume that's where intensity was measured when distance isn't given. Other emitters may report intensity at ranges from 10 mm to 50 mm, usually aligned to the distance for which the emitter is focused. Large variances will be observed in the output power advertised on the data sheet, based on that working distance. However, the differences in the raw number may overstate the differences in actual irradiance emitted.

The two charts to the right show the intensity performance over distance of the Dymax BlueWave® AX-550 V1.0 and the BlueWave® AX-550 V2.0. Over long distances, both charts show a linear decrease in intensity with distance. This is typical for UV emitters, as the light dissipates as it gets farther from the source. However, close to the emitter there is an obvious difference. In the chart for the V1.0, there is a hump of increased intensity that occurs at around 25 mm from the glass. This is an artifact of the emitter being focused at 25 mm working distance for curing applications. The design of that emitter is such that at closer distances, before the light reaches its focus point, the intensity is lower. This emitter might fare poorly in an application like high-speed printing, where the material needs to be passed very close to the array surface to ensure the largest dose in the shortest time.

See the example emitters in Table 1, below. The two have similar LED power, but one is unfocused, for working close to the emitter, and the second is focused at 25 mm.

Example: Emitter A - 16 W/cm^2, measured at the glass
Emitter B - 4 W/cm^2, measured at 25 mm

Emitter A is not focused, and is designed to blast high power very close to the surface. Pull the substrate away and the intensity drops off at an incredible rate. Emitter B is less "powerful" at the glass, but performs much better as the substrate is pulled away. Figure 3, below, shows a plot of the intensity vs. working distance for the two emitters. Emitter A's intensity drops to almost nothing by the time the substrate is 2 inches away, while Emitter B is still effective at 5 and 7 cm.

Table 1. Intensity vs. Working Distance

	Emitter A	Emitter B
Curing Area	75 mm x 25 mm	75 mm x 25 mm
Wavelength	385 nm	385 nm
Intensity	16 W/cm^2	4 W/cm^2
Measured	At Array Surface	25 mm Working
Working Distance Performance		
1 mm	16,0 W/cm^2	8,5 W/cm^2
5 mm	12,0 W/cm^2	7,0 W/cm^2
10 mm	8,5 W/cm^2	6,2 W/cm^2
15 mm	6,0 W/cm^2	5,4 W/cm^2
20 mm	4,0 W/cm^2	4,5 W/cm^2
25 mm	2,7 W/cm^2	4,0 W/cm^2
30 mm	1,9 W/cm^2	3,8 W/cm^2
50 mm	0,7 W/cm^2	2,5 W/cm^2

Figure 1. Dymax BlueWave® AX-550 V1.0 Focused at 25 mm

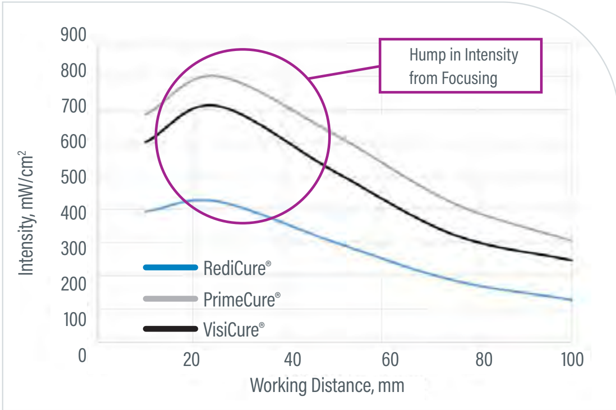


Figure 2. Dymax BlueWave® AX-550 V2.0 Focused for Uniform Intensity Reduction

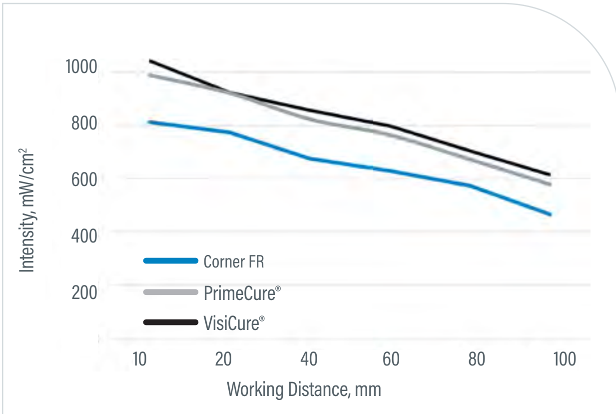
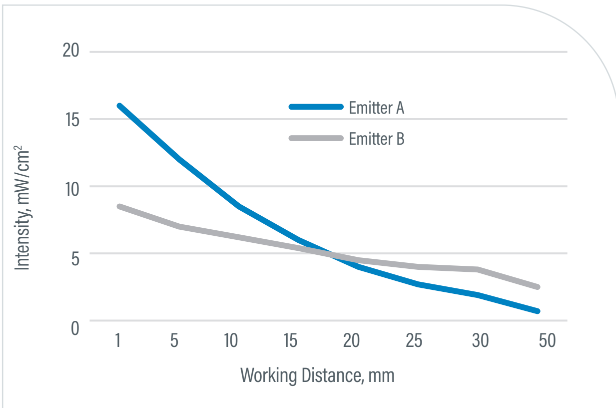


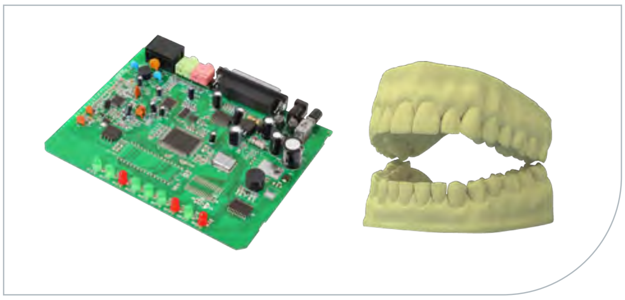
Figure 3. Intensity vs. Working Distance



Despite similar LED power output, these arrays will perform very differently based on the working distance of the application

That effectiveness at longer distances is very important when curing parts that have variable surface geometries. A PC board with several components of varying height, or dental pieces where the surface height changes considerably over a cross section will have the working distance and the total UV dose also change considerably. The user may still need the depth of cure to get the dose all the way through the part. In this case, Emitter B may be delivering much more power where it matters to the application, though it appears barely comparable if one only looks at the rated power number on the data sheet for intensity.

Figure 4. PCB (left) and Dental Mold (right); Variable Surface Geometries



The PC board above has large capacitors that extend off the board. The dental mold has peaks and pits that conform to the contours of the mouth. The cross section of each varies several inches in distance when placed under an emitter.

Figure 5. High Uniformity

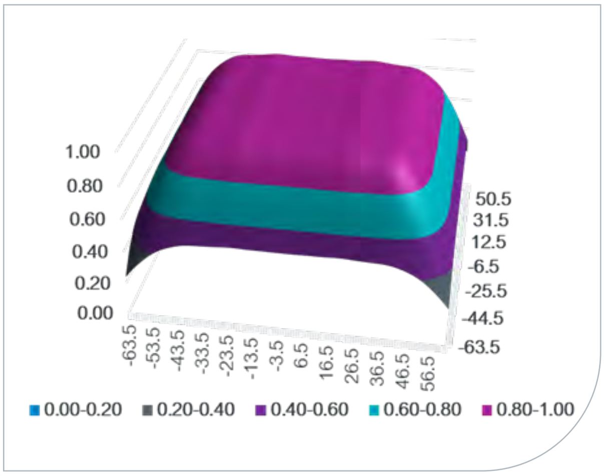
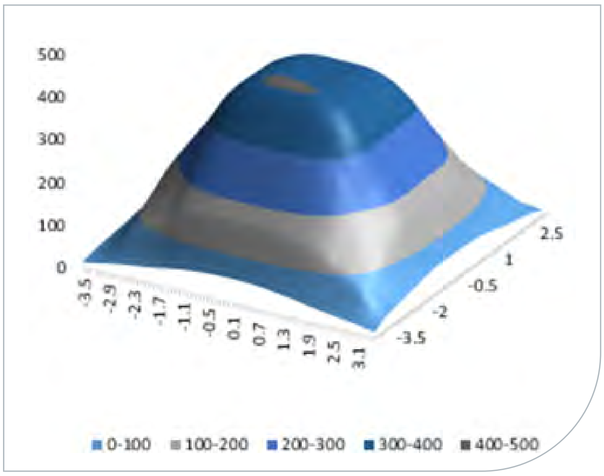


Figure 6. Low Uniformity



The emitters above have similar output at their central peaks, but the Low Uniformity emitter maintains that over a smaller area. The intensity toward the edges is much lower in the Low Uniformity emitter.

Further, consider the uniformity of the exposure. It is most common on emitter data sheets to provide a single intensity value. This is usually a peak value measured at a point central to the stated curing area. However, the power delivered is never constant over the curing area of an emitter. All emitters have some divergence or splay of their light outward from the emission window. Optics can be used to focus the light at a desired working distance, but cannot totally prevent divergence.

The plots to the left show the uniformity over the curing area for a pair of ~13 x 13 cmm emitters. The High Uniformity emitter has a flat profile over most of the curing area. The Low Uniformity emitter has a peak in the center, but a rapid and steep drop from its peak to the edges of the curing area. Thus, the intensity delivered to the substrate can vary significantly based on the position of the substrate under the emitter.

Uniformity is not constant over distance. On the following page are examples of uniformity and distance plots to show how performance varies over distance and area. The intensity is high close to the emitter, but the light is very close to the center. As the distance increases the intensity drops, but the light splays to cover more area. The size and shape of the part being cured must always be considered, because parts outside the peak irradiating area of the emitter will receive a much lower dose over the same time period. This impacts the potential throughput; to receive the same dose at the edge, the part must be exposed longer. Variations in uniformity tend to be exacerbated by extended working distances. The drop in intensity becomes more extreme as the target is moved further from the emitter surface.

Figure 7. Intensity by Working Distance

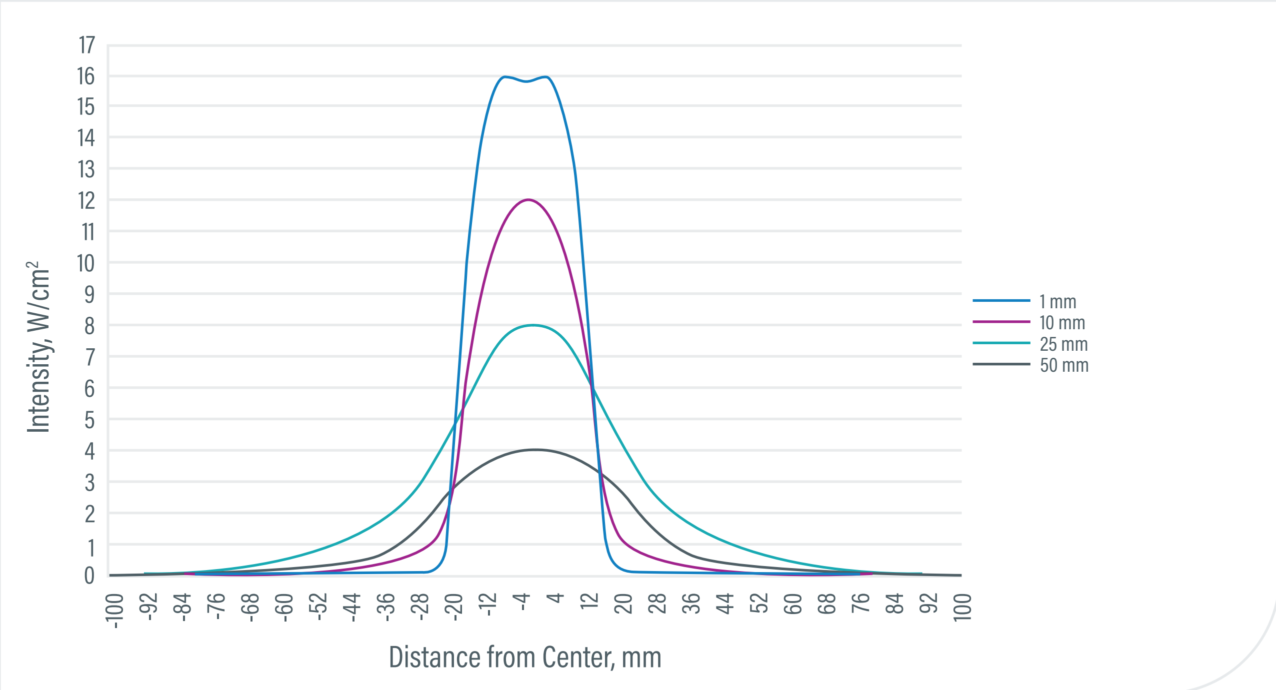
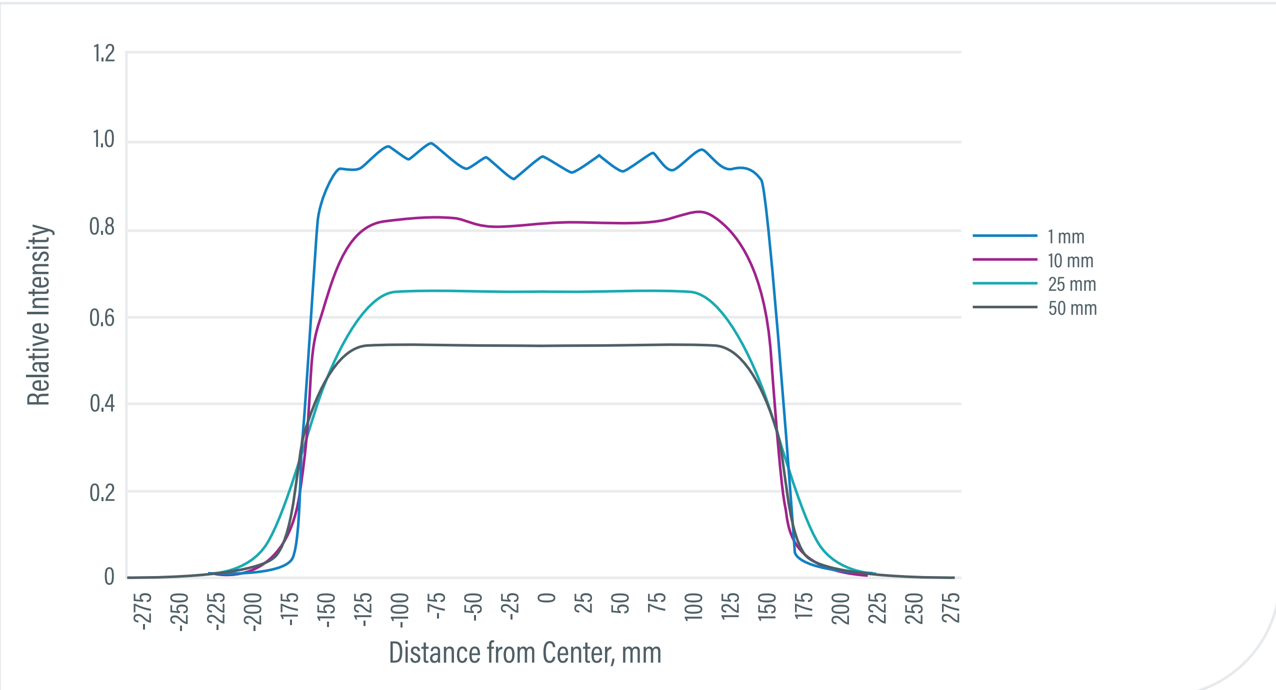
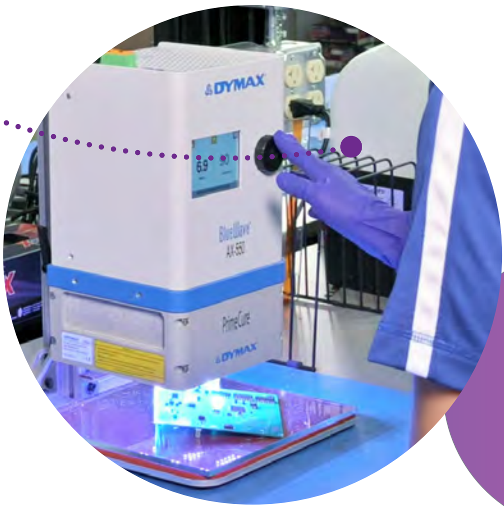


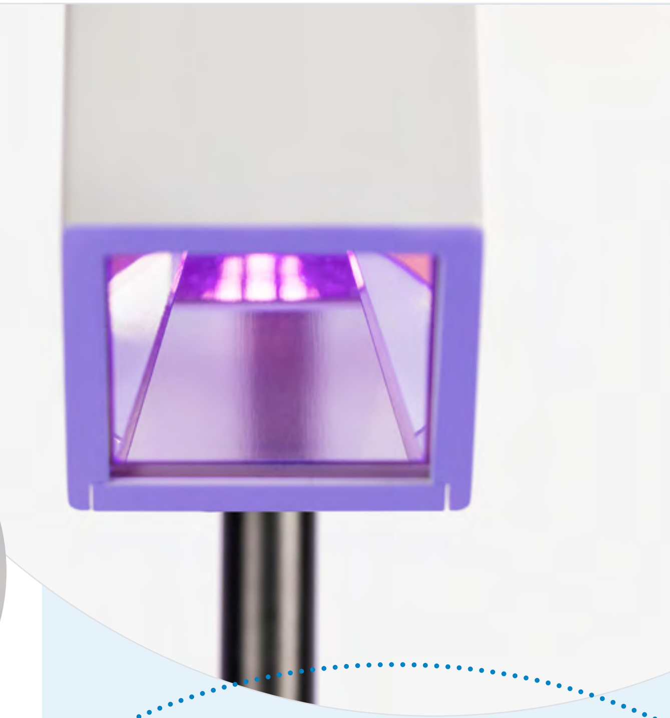
Figure 8. Intensity by Working Distance

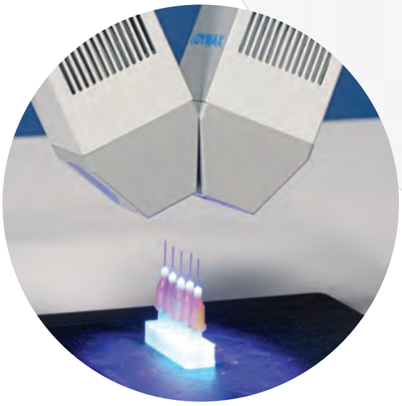


Conclusion

Ultimately, what is advertised on a data sheet and what is truly delivered to the target can be very different. Process engineers designing a curing operation must always consider the size of the part in relation to the curing area, and the performance of the emitter at the intended working distance (or distances) of the process. While detailed data sheets and charts are a helpful guide, there is no true substitute for testing the equipment with the parts and formulations for which the process will be designed. Good practice requires creating as close a facsimile as possible to the eventual process and verifying performance through tests of the formulation and radiometric readings of the output from the curing device. Only with the knowledge of the true performance at all points, can a process engineer truly calculate the exposure time needed to complete the curing operation. And only then can an engineer safely design the operation to be robust and reliable, and accurately calculate the throughput.







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