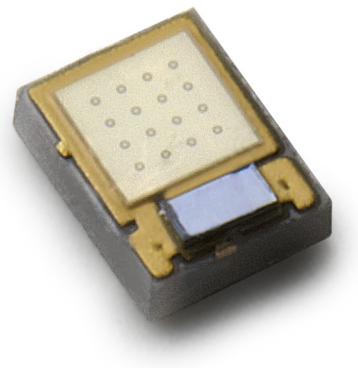
LUMILEDS

GENERAL ILLUMINATION

LUXEON Z UV

Assembly and handling information



Introduction

This application brief addresses the recommended assembly and handling procedures for LUXEON Z UV emitters. Proper assembly, handling, and thermal management, as outlined in this application brief, ensure high optical light output and long light output maintenance for LUXEON Z UV emitters.

Scope

The assembly and handling guidelines in this application brief apply to all the LUXEON Z UV part numbers LHUV-abbb-cddd where:

a –	for future additional requirements for this product
bbb –	beginning of peak wavelength bin in 5nm interval (e.g. 395 designates 395–400nm range)
c –	for future additional requirements for this product
ddd –	minimum total radiometric power in mW (e.g. 500 refers to min 500mW)

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1. Component

1.1 Description

The LUXEON Z UV emitter is an ultra-compact, surface mount, high-power ultra-violet (UV) LED with peak wavelength ranging from 380nm to 430nm. Each LUXEON Z UV emitter consists of a high brightness InGaN chip on a ceramic substrate. The ceramic substrate provides mechanical support and provides a thermal path from the LED chip to the bottom of the emitter. An interconnect layer electrically connects the LED chip to cathode and anode pads of equal size on the bottom of the ceramic substrate. The cathode of the LUXEON Z UV emitter is marked with a small notch in the center of the electrode (see Figure 1).

The top of the LUXEON Z UV is covered with a layer of silicone to shield the chip from the environment. The bottom of the LUXEON Z UV emitter contains two equally sized metallization pads for the anode and cathode.

All LUXEON Z UV emitters contain a transient voltage suppressor (TVS) chip which protects the LED chip against electrostatic discharge (ESD) events. The top surface of the LUXEON Z UV emitter has a flat top surface as shown in Figure 1.

As with any other UV light source, proper safety precautions must be followed to protect eyes and skin from UV exposure when operating these light sources. A UV caution label is attached to each reel shipped.

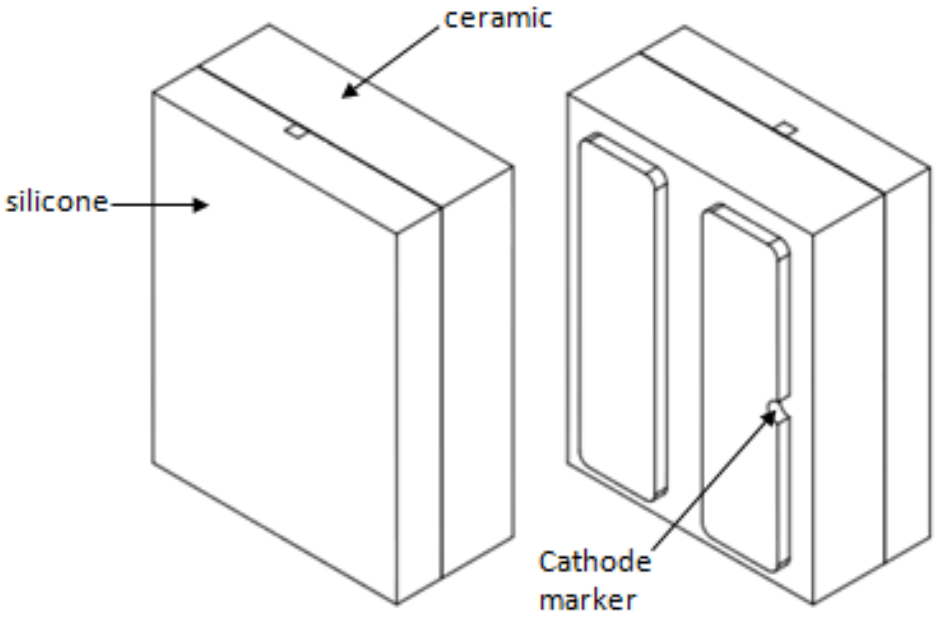


Figure 1. 3D renditions of LUXEON Z UV. Top view (left) and bottom view (right).

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1.2 Optical Center

The theoretical optical center of the LUXEON Z UV emitter is 0.625mm from the top and 0.650mm from the side edges of the ceramic substrate (see Figure 2).

Note that when designing secondary optics for LUXEON Z UV emitters, the lens material selected should be able to withstand prolonged UV exposure. For example, a lens which is made of untreated standard grade polycarbonate (PC) absorbs UV light and turns yellowish over time, which, in turn, reduces the light output performance of the whole LED system. Lumileds recommends that customers discuss the impact of prolonged exposure to UV light with lens suppliers when selecting appropriate lens materials.

1.3 Handling Precautions

The LUXEON Z UV emitter is designed to maximize light output and reliability. However, improper handling of the emitter may damage the LED chip and affect the overall performance and reliability. In order to minimize the risk of damage to the LED chip during handling, LUXEON Z UV emitters should only be picked up manually from the side of the ceramic substrate as shown in Figure 3.

When handling finished boards containing LUXEON Z UV emitters, do not touch the top surface with any fingers (see Figure 4a) or apply any pressure to it. Also, do no turn over the board for probing, if the electrodes are at the back of the board, or stack multiple boards on top of each other (see Figure 4b). A rough or contaminated surface, which is placed on top of a LUXEON Z UV emitter, may damage the silicone overcoat of the emitter. Furthermore, any pressure applied onto the LUXEON Z UV emitter during probing may damage the silicone layer or the chips underneath.

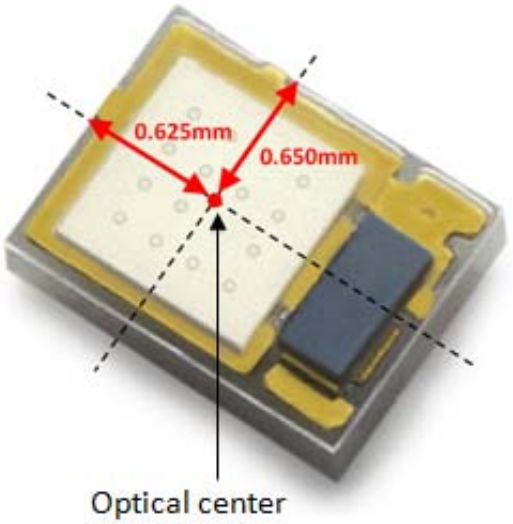


Figure 2. The optical center of the LUXEON Z UV emitter is 0.625mm from the top and 0.650mm from the side edges.

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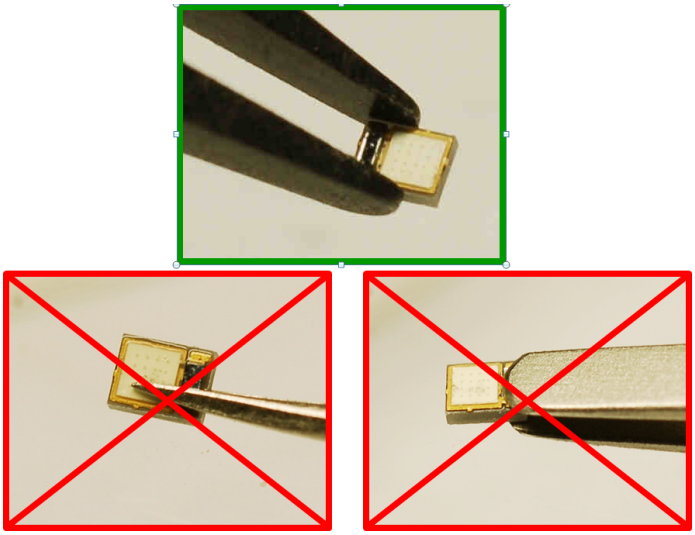


Figure 3. Correct handling (top) and incorrect handling (top) of LUXEON Z UV emitters.

1.4 Cleaning

The LUXEON Z UV emitter should not be exposed to dust and debris. Excessive dust and debris may cause a drastic decrease in optical output. In the event that the surface of a LUXEON Z UV emitter requires cleaning, a compressed gas duster at a distance of 6" away will be sufficient to remove the dust and debris or an air gun with 20 psi (at nozzle) from a distance of 6". Make sure the parts are secured first.

If there is any solder flux residue on the top of the package, it may oxidized and turn brown during LED operation. In general any foreign contamination which is not transparent to blue or UV light should be removed to prevent possible photo-thermal chemical reaction.

1.5 Electrical Isolation

The LUXEON Z UV emitter contains only two electrical pads on the bottom of the ceramic substrate with a spacing of 0.25mm between them. In order to avoid any electrical shocks and/or damage to the LUXEON Z UV emitter, each design needs to comply with the appropriate standards of safety and isolation distances, known as clearance and creepage distances, respectively (e.g. IEC60950, clause 2.10.4).

1.6 Mechanical Files

Mechanical drawings for LUXEON Z UV (2D and 3D) are available on the Lumileds website at lumileds.com.

1.7 Soldering

LUXEON Z UV emitters are designed to be soldered onto a Printed Circuit Board (PCB). For detailed assembly instructions, see Section 4.

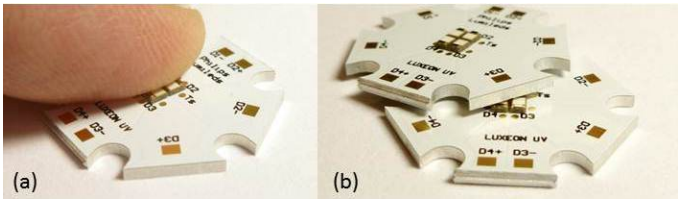


Figure 4. Do not touch the top of surface of the LUXEON Z UV emitter when handling a finished board (a) or stack boards with one or more LUXEON Z UV emitters on top of each other (b).

2. LUXEON Z UV Printed Circuit Board Design Rules

The LUXEON Z UV emitter is designed to be soldered onto a Metal Core PCB (MCPCB) or a ceramic PCB such as aluminum nitride (AlN). Table 1 shows the differences between these two PCB substrates.

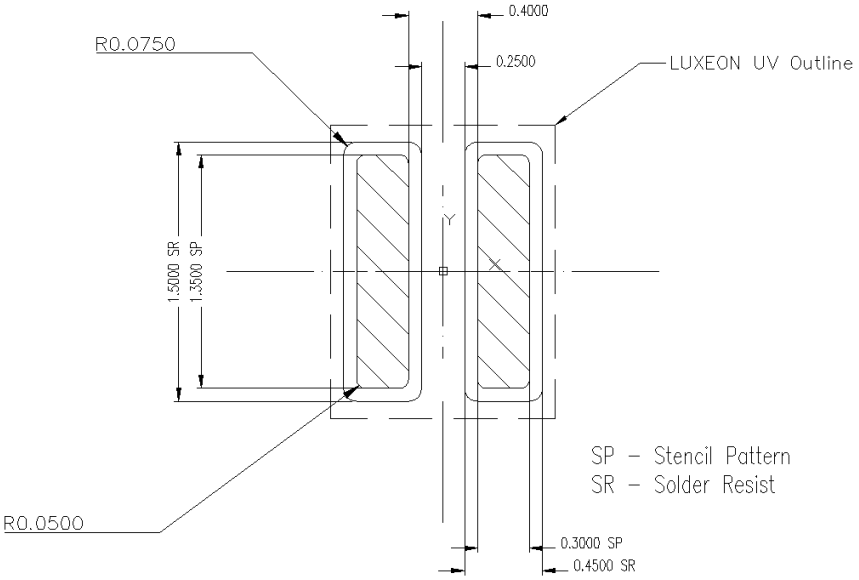
Table 1. MCPCB versus Ceramic PCB Comparison

	MCPCB	ALN CERAMIC PCB
Cost	Low	High
Coefficient of thermal expansion (CTE)	Low CTE matching to LUXEON Z UV	High CTE matching to LUXEON Z UV
LED assembly packing density (thermal resistance consideration)	Suitable for low density with larger LED to LED spacing	Good for high density where LED to LED spacing may be as low as 200µm.
Mechanical assembly and handling	Generally easy as board does not easily break	Extra precaution to prevent ceramic breakage

To ensure optimal operation of the LUXEON Z UV emitter, the PCB should be designed to minimize the overall thermal resistance between the LED package and the heat sink.

2.1 LUXEON Z UV Footprint and Land Pattern

The LUXEON Z UV emitter has two pads that need to be soldered onto corresponding pads on a PCB to ensure proper electrical operation. Figure 5 shows the recommended footprint design for a single LUXEON Z UV emitter.



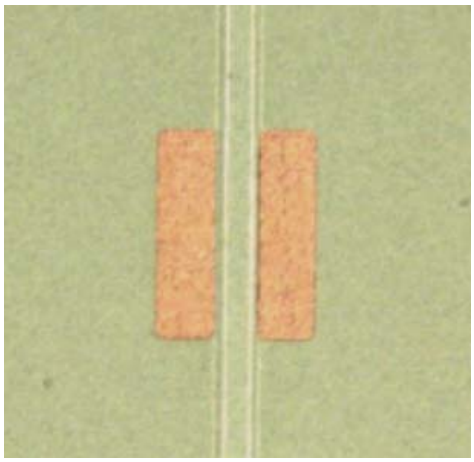


Figure 5. Recommended PCB Footprint for LUXEON Z UV (top). SR denotes solder resist opening and SP denotes stencil pattern. All dimensions are in mm. Bottom image shows actual PCB footprint layout.

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The electrical pads of the LUXEON Z UV emitter also serve as thermal pads between the LED and the PCB. To enhance heat dissipation from the LUXEON Z UV emitter into the PCB, it is best to extend the copper area around each electrode approximately 4mm from the center of the LUXEON Z UV emitter, where possible. Furthermore, it is desirable to keep the thermal resistance values of the two copper pads on the PCB underneath each LUXEON Z UV emitter approximately equal to ensure a balanced heat transfer from the LUXEON Z UV emitter through both electrodes for optimum thermal performance.

Figure 6 shows an example of the pad layouts for a densely packed 2x2 LUXEON Z UV array (top right), connected in series on an aluminum metal core PCB (MCPCB) starboard. The spacing between these four LUXEON Z UV emitters is 200µm. The gerber files for both starboards are available from the Lumileds website at lumileds.com.

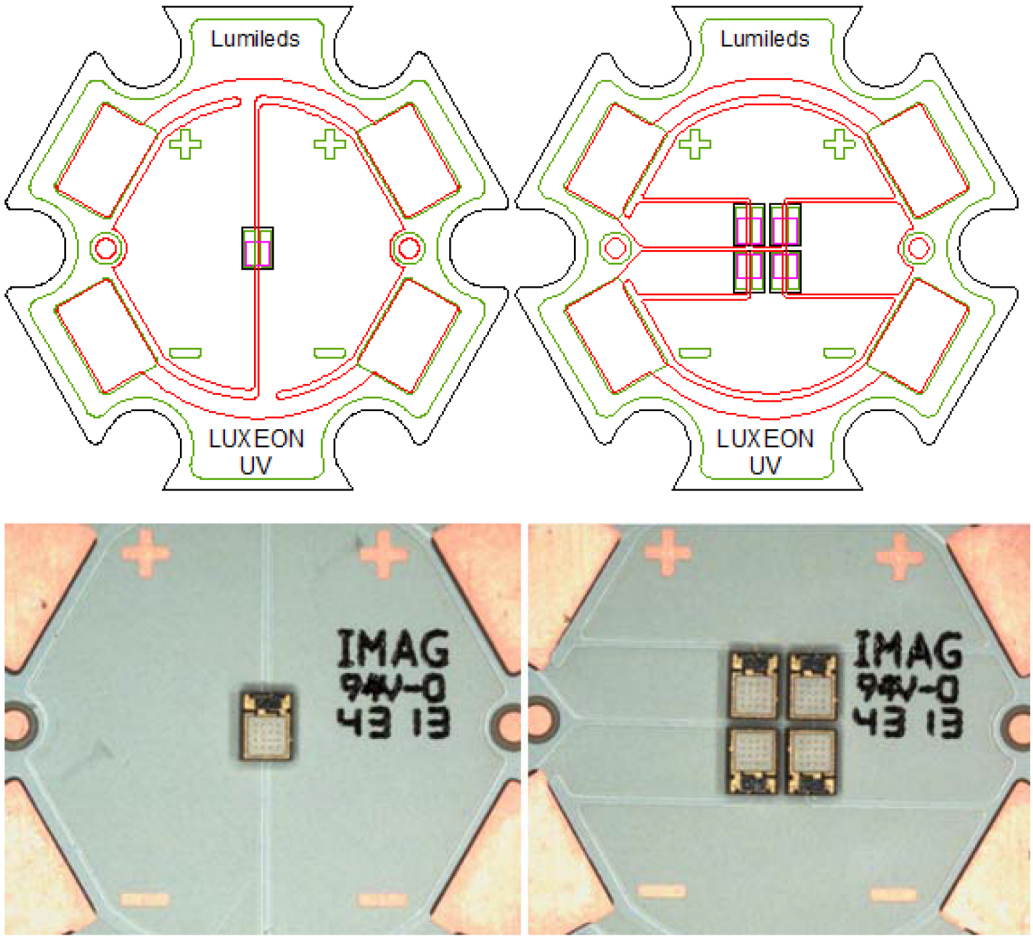


Figure 6. 1-up (top left) and 4-up (top right) LUXEON Z UV metal core PCB star board design. Green represents the solder mask, red the copper layer, pink the chip location and black rectangle is the LUXEON Z UV package outline. Bottom photos show actual parts after reflow on these boards.

2.2 Surface Finishing

Lumileds recommends using either a high temperature organic solderability preservative (OSP) or electroless nickel immersion gold (ENIG) on the copper layer of the PCB.

2.3 Minimum Spacing

Lumileds recommends a minimum edge to edge spacing between LUXEON Z UV emitters of 200 µm to account for manufacturing tolerances such as package size and pick-and-place placement tolerance. Placing multiple LUXEON Z UV emitters too close to each other may adversely impact the ability of the PCB to dissipate the heat from the emitters.

3. Thermal Measurement Guidelines

3.1 Thermal Basics

This section provides general guidelines on how to determine the junction temperature of a LUXEON Z UV emitter in a stand-alone or 4-up array configuration in order to verify that the junction temperature in the actual application during regular operation does not exceed the maximum allowable temperature specified in the datasheet.

The typical thermal resistance $R\theta_{j\text{-thermal pad}}$ between the junction and the thermal pad for LUXEON Z UV is specified in the LUXEON Z UV datasheet. In LUXEON Z UV, both the electrode pads serve as thermal pads. With this information, the junction temperature T_j can be determined according to the following equation:

$$T_j = T_{\text{thermal pad}} + R\theta_{j\text{-thermal pad}} \cdot P_{\text{electrical}}$$

In this equation $P_{\text{electrical}}$ is the electrical power going into the LUXEON Z UV emitter and $T_{\text{thermal pad}}$ is the temperature at the bottom of one of the LUXEON Z UV electrodes, assuming both LUXEON Z UV electrodes are connected to copper pads on the PCB with approximately the same thermal resistance.

3.2 Temperature Sensor Pad (T_s) and Thermocouple (TC) Attachment

In typical applications it may be difficult, though, to measure the thermal pad temperature $T_{\text{thermal pad}}$ directly. Therefore, a practical way to determine the LUXEON Z UV junction temperature is by measuring the temperature T_s of a predetermined sensor pad on the PCB right next to the LUXEON Z UV emitter with a thermocouple (TC). The junction temperature can then be calculated as follows:

$$T_j = T_s + R\theta_{j\text{-}s} \cdot P_{\text{electrical}}$$

In the above equation $P_{\text{electrica}}$ is the combined electrical power going into the LUXEON Z UV emitters. The thermal resistance from junction to the T_s point, $R\theta_{j\text{-}s}$ depends on several factors such as the PCB type and construction (e.g. MCPCB dielectric layer thickness), the location of the T_s point, type and volume of the adhesive used to attach the TC wire, and the LED emitter packing density.

To ensure accurate readings, the TC must make direct contact with the copper of the PCB onto which the LUXEON Z UV electrode pads are soldered, i.e. any solder mask or other masking layer must first be removed before mounting the TC onto the PCB. The TC must be attached as close as possible to the primary heat flow path of the LED emitter pad. In LUXEON Z UV, this will be the position next to the long side of the LUXEON Z UV emitter as shown in Figure 7. Lumileds recommends two-part Artic Silver™ thermal adhesive in combination with a TC wire gauge of AWG 40 or 36. Excessive thermal adhesive may impact the accuracy of the T_s temperature reading. In particular, if the thermal adhesive spills over onto the top of the package or blocks some side light, the Ts reading may increase due to absorption of the optical energy of the UV light (Figure 8). The use of non-conductive thermal epoxy is not recommended since there may be a possibility of getting some epoxy residue underneath the TC wire tip and the exposed PCB copper trace which will affect the $R\theta_{j\text{-}s}$ measurement.

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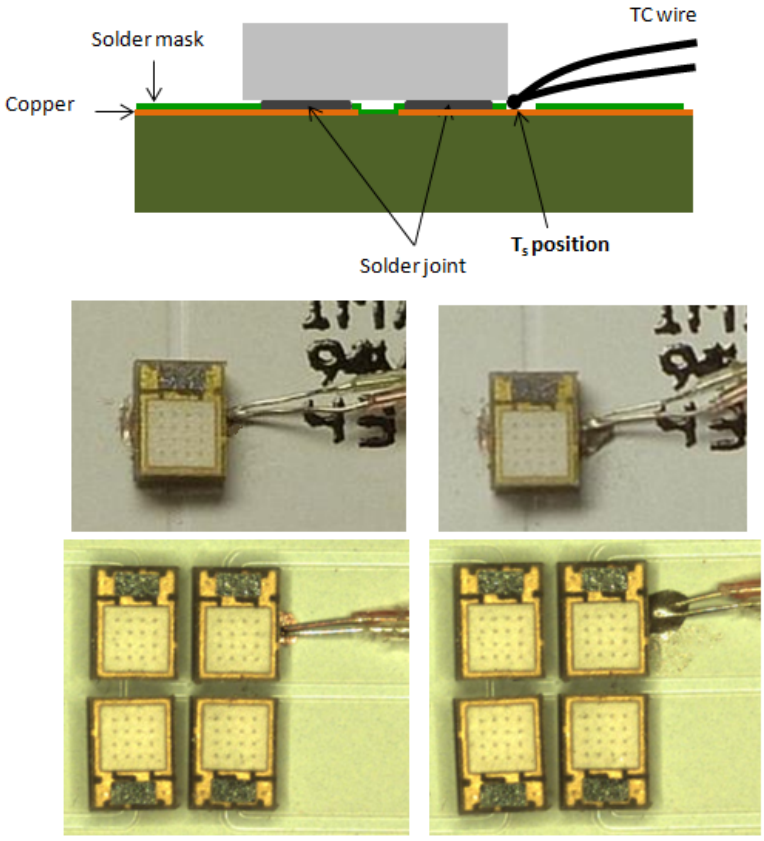


Figure 7. Diagram showing the recommended location of T_s point (top). Middle left and bottom left photos show the TC wire is placed close to the package (adjacent to the anode or cathode thermal pads) with solder mask layer removed exposing the underlying copper prior to thermal adhesive application. Middle right and bottom right photos show the right amount of thermal adhesive application.

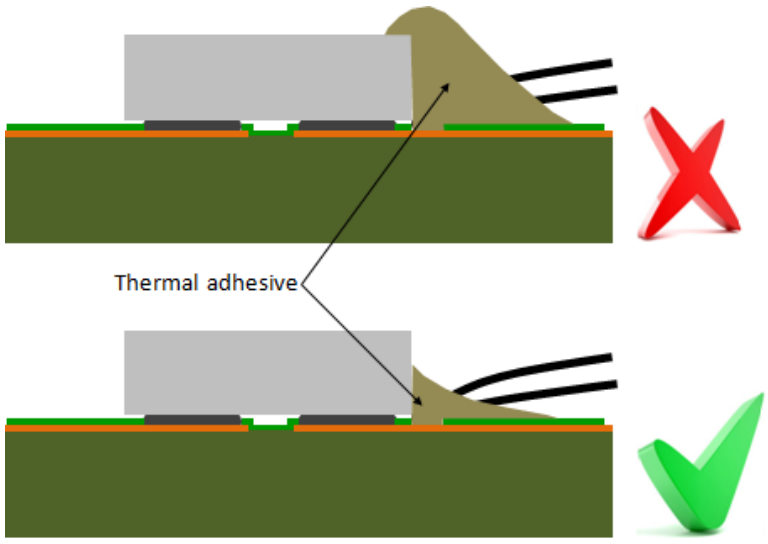


Figure 8. Top diagram shows spillover of thermal adhesive to the top of the package. Bottom diagram shows good amount of thermal adhesive coverage to secure the TC wire.

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3.3 Effect of Placing T_s Point Further Away from LED Package

As described in 3.2, one of the factors that can affect the T_s measurement is its location. Ideally the most accurate method to determine T_j is by placing the TC wire directly underneath the center of the thermal pad and then using the typical LED package thermal resistance which is widely quoted in any LED datasheet to calculate the T_j.

Such measurements are difficult to make in real life situations, so the next best step is to place the TC wire as close as possible to the thermal pad.

Figure 9 and Table 2 show representative thermal simulation results for a LUXEON Z UV 380nm package. These simulations highlight the impact of the location of the T_s point on the overall $R\theta_{j\text{-}s}$ value. In this simulation, the total heat dissipation power is set to 1.50W. T_{s1} is the recommended T_s point by Lumileds since it is the closest to the LED package when it comes to placing the TC wire while T_{s2} point is 200µm further away from the T_{s1} point resulting in a drop of about 2°C.

In this simulation example, if the actual TC wire is accidentally positioned at location T_{s2} instead of location T_{s1}, the T_j calculation will yield 34.67°C + (7.68K/W)*(1.5W) = 46.19°C, which is underestimating the actual T_j by about 2°C.

Table 2: Simulated temperature of various points in Figure 9 (bottom table) and the thermal resistance values between various points

TEMPERATURE LOCATION	T_J	$T_{THERMAL\ PAD}$	T_{S1}	T_{S2} (200MM AWAY FROM T_{S1})
Simulated temperature (°C)	48.26	39.56	36.74	34.67

PARAMETER	THERMAL RESISTANCE (K/W)
$R\theta_{j\text{-}thermalpad}$	5.80
$R\theta_{j\text{-}s1}$	7.68
$R\theta_{j\text{-}s2}$	9.06

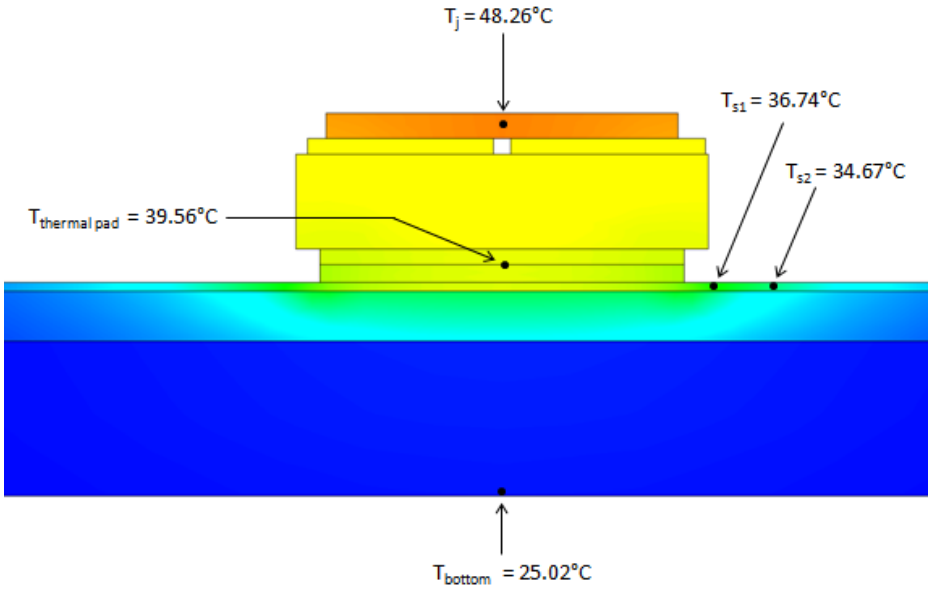


Figure 9. Thermal simulation result of a typical LED package mounted on MCPCB, showing the contour temperature on one cross section through the LED package.

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3.4 Thermal Measurement Result

A 1.0 mm thick Al-MCPCB board with 2oz copper and 100 µm thick Arlon 92ML (thermal conductivity 2.0 W/(m.K) dielectric layer was used in the characterization of the thermal resistance from junction to the bottom of PCB ($R\theta_{j\text{-}bottom}$) and junction to T_s point ($R\theta_{j\text{-}s}$) as shown in Table 3. The thermal resistance calculation is based on the equation as described earlier in section 3.2.

$$T_j = T_s + R\theta_{j\text{-}s} \cdot P_{electrical}$$

LED board configurations with a larger number of closely packed LUXEON Z UV emitters may require thermal modeling to determine the junction temperature of those LUXEON Z UV emitters in the center of the array which are likely to be the hottest and not easily accessible.

Table 3. Typical thermal (electrical) resistance values for $R\theta_{j\text{-}s}$ and aluminum MCPCB for 1-up and 4-up designs.

DESIGN	WAVELENGTH BIN (NM)	TYPICAL ($R\theta_{J\text{-}S}$) (K/W)	TYPICAL ($R\theta_{J\text{-}BOTTOM}$) (K/W)
1-up	380–385	7.4	15.1
	385–390	7.4	15.1
	390–395	6.1	12.6
	395–400	5.5	11.4
	400–405	5.5	11.4
	405–410	5.5	11.4
	410–415	4.9	10.2
	415–420	4.2	9.0
	420–425	4.2	9.0
	425–430	4.2	9.0
4-up (in series)	380–385	2.4	6.8
	385–390	2.4	6.8
	390–395	2.0	5.9
	395–400	1.8	5.5
	400–405	1.8	5.5
	405–410	1.8	5.5
	410–415	1.6	5.0
	415–420	1.4	4.6
	420–425	1.4	4.6
	425–430	1.4	4.6

4. Assembly Process Guidelines

4.1 Stencil Design

The appropriate stencil design for the LUXEON Z UV emitter is included in the PCB footprint design (see Figure 5). The recommended stencil thickness is 100µm. The slightly smaller stencil opening compared to the solder resist opening reduces the chance for solder paste bridging during the stencil printing process (the spacing between the electrodes is only 250µm).

4.2 Solder Paste

Lumileds recommends a lead-free no clean solder paste to mount LUXEON Z UV emitters onto a PCB. Lumileds successfully tested a solder paste from Alpha® SAC305-CVP390-M20 type 3. However, since application environments vary widely, Lumileds recommends that customers perform their own solder paste evaluation in order to ensure it is suitable for the targeted application.

4.3 Solder Paste Screen Printing

In general there are three methods to align the stencil to the PCB during solder paste screen printing:

1. The stencil is manually aligned to the PCB prior to printing. No adjustments are made during printing.
2. The stencil is manually aligned to the PCB prior to printing. During printing, the machine keeps track of the PCB fiducial mark(s) and makes any necessary adjustments to maintain proper alignment with the PCB.
3. A technician performs a crude alignment of the stencil to the PCB. During printing, the machine keeps track of the PCB fiducial mark(s) and the stencil fiducial mark(s) and maintains proper alignment between the fiducials throughout the process.

Method 1 has the worst accuracy and repeatability of the three methods discussed. Method 2 offers the same accuracy as method 1 but ensures better repeatability. Method 3 has the best accuracy and best repeatability of the 3 methods discussed.

Depending on what screen printing method is used, the size of the anode and cathode solder mask openings on the PCB may have to be enlarged to compensate for any misalignments between the stencil and the PCB panel. Note, though, that any enlargement in the solder mask opening for anode and cathode pads may reduce the solder reflow placement accuracy.

In order to ensure proper alignment between the stencil and the PCB as well as reliable transfer of solder paste onto the PCB, all PCB panels should be rigidly supported during solder paste printing. Instead of placing the PCB panel on multiple support pins, it is best to place the PCB panel on a single solid plate. This is particularly important for PCB panels which contain v-scores or perforated holes for de-panel purposes

Figure 10 shows the outcome of a well controlled stencil printing process according to method 3 above. In this example, the recommended stencil pattern of Figure 5 was used in combination with a stencil thickness of 100um and a solder paste from Alpha® (SAC305-CVP390-M20 type 3).

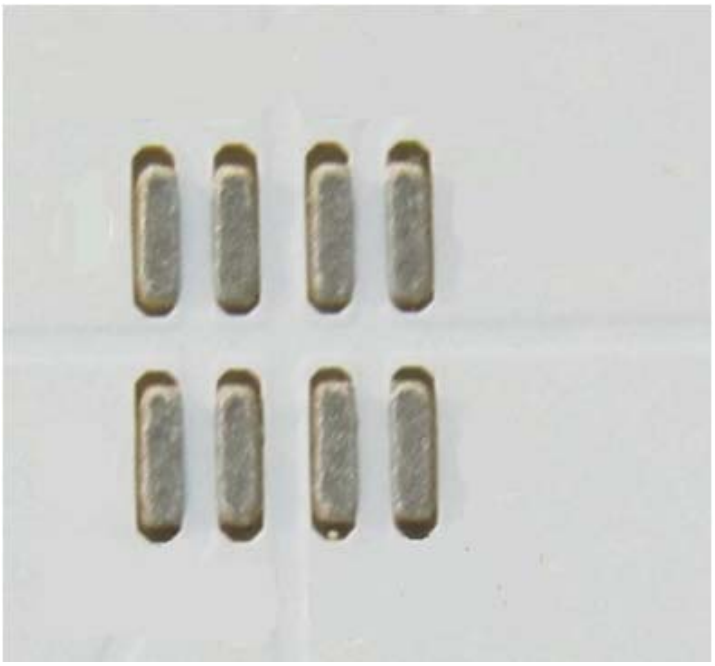


Figure 10. An example of good stencil printing on 4-up MCPCB star board.

4.4 Pick-and-Place

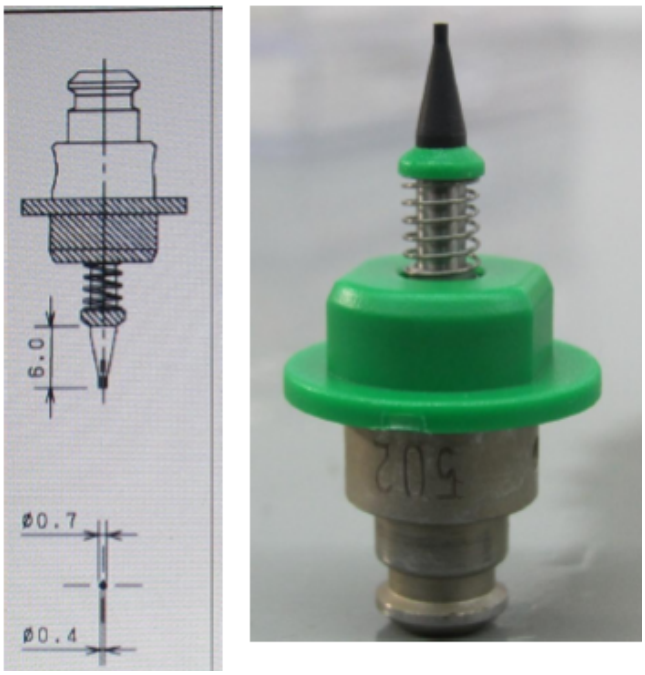
Automated pick and place equipment provides the best handling and placement accuracy for LUXEON Z UV emitters. Figure 11 and Figure 12 show two pick and place nozzle designs and corresponding machine settings which were successfully used to mount LUXEON Z UV emitters onto the 4-up boards with 200um spacing using footprint layout in Figure 5 with pick and place equipment from Juki KE2080L and Samsung SM421. Based on these pick and place experiments, Philips advises customers to take the following general pick and place guidelines into account:

1. The nozzle tip should be clean and free of any particles since this may interact with the silicone coating of the LUXEON Z UV package during pick and place.
2. During setup and any initial production runs, it is a good practice to inspect the top surface of the LUXEON Z UV emitters under a microscope to ensure the emitters are not accidentally damaged by the pick and place nozzle.

Note that pick and place nozzles are customer specific and are typically machined to fit specific pick and place tools.

Since LUXEON Z UV has no primary optics or lens which can act as a mechanical enclosure protection for the LED chips, the pick-up and placement force applied to the top of the package should be kept to a minimum. The placement force (consisting of impact force and dwell force, also known as static force) depends on the nozzle tip material, nozzle spring stiffness, nozzle diameter, vacuum pressure, over travel distance, PCB height differences and PCB warping.

Standard off-the-shelf nozzle “502”



PICK AND MOUNT INFORMATION		VISION INFORMATION	
XY	Fast2	Centering method	Laser
Pick depth	0mm	LNC 60/61 Laser	-0.48
Picking stroke	0	Comp shape	Corner Square
Pick Z down	Fast2		
Pick Z up	Fast2		
Placing stroke	0		
Place Z down	Fast2		
Place Z up	Fast2		
Theta (measure)	Fast		
Theta (other)	Fast		

Figure 11. Pick and place nozzle design and corresponding machine settings for Juki KE2080L in combination with the off-the-shelf nozzle 502. These machine settings were successfully used to place LUXEON Z UV emitters onto a PCB.

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Standard off-the-shelf nozzle “CN040”



PICK AND MOUNT INFORMATION		PICK AND MOUNT INFORMATION	
Pick Height	0.2mm	Speed - XY	1
Mount Height	0mm	Speed – Z Pick Down	1
Delay – Pick Up	30ms	Speed – Z Pick Up	1
Delay – Place	40ms	Speed – R	1
Delay – Vac Off	0	Speed – Z Place Down	1
Delay – Blow On	0	Speed – Z Place Up	1
		Z Align Speed	1
		Soft Touch	Pick and Mount

Figure 12. Pick and place nozzle design and corresponding machine settings for Samsung SM421 in combination with the off-the-shelf nozzle NC040. These machine settings were successfully used to mount LUXEON Z UV emitters onto a PCB.

4.5 Reflow Accuracy

Using the solder resist and stencil pattern layout as shown in Figure 5, Lumileds has determined the placement accuracy after reflow to be within a standard deviation of 24µm in the x and y direction. For a small and lightweight package like LUXEON Z UV, the surface tension of the molten solder is able to realign the LUXEON Z UV package to the nominal position of the footprint layout.

Figure 13 shows a typical self reflow alignment of a 4-up board configuration with 200um spacing using the recommended layout as specified in Figure 5 and following the assembly process guidelines as described here.

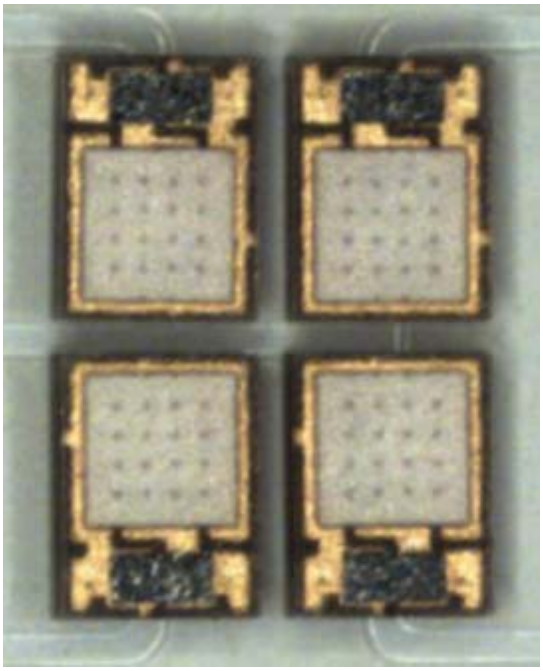


Figure 13. LUXEON Z UV 4-up star board showing good package alignment after reflow.

5. Packaging Considerations — Chemical Compatibility

The LUXEON Z UV package contains a silicone overcoat to protect the LED chip. As with most silicones used in LED optics, care must be taken to prevent any incompatible chemicals from directly or indirectly reacting with the silicone.

The silicone overcoat in LUXEON Z UV is gas permeable. Consequently, oxygen and volatile organic compound (VOC) gas molecules can diffuse into the silicone overcoat. VOCs may originate from adhesives, solder fluxes, conformal coating materials, potting materials and even some of the inks that are used to print the PCBs.

Some VOCs and chemicals react with silicone and produce discoloration and surface damage. Other VOCs do not chemically react with the silicone material directly but diffuse into the silicone and oxidize during the presence of heat or light. Regardless of the physical mechanism, both cases may affect the total LED light output. Since silicone permeability increases with temperature, more VOCs may diffuse into and/or evaporate out from the silicone.

Careful consideration must be given to whether LUXEON Z UV emitters are enclosed in an “air tight” environment or not. In an “air tight” environment, some VOCs that were introduced during assembly may permeate and remain in the silicone overcoat. Under heat and exposure to blue and UV light, the VOCs inside the silicone overcoat may partially oxidize and create a silicone discoloration, particularly on the surface of the LED where the flux energy is the highest. In an air rich or “open” air environment, VOCs have a chance to leave the area (driven by the normal air flow). Transferring the devices which were discolored in the enclosed environment back to “open” air may allow the oxidized VOCs to diffuse out of the silicone overcoat and may restore the original optical properties of the LED.

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Determining suitable threshold limits for the presence of VOCs is very difficult since these limits depend on the type of enclosure used to house the LEDs and the operating temperatures. Also, some VOCs can photo-degrade over time.

Table 4 provides a list of commonly used chemicals that should be avoided as they may react with the silicone material. Note that Lumileds does not warrant that this list is exhaustive since it is impossible to determine all chemicals that may affect the LED performance.

The chemicals in Table 4 are typically not directly used in the final products that are built around LUXEON Z UV LEDs. However, some of these chemicals may be used in intermediate manufacturing steps (e.g. cleaning agents). Consequently, trace amounts of these chemicals may remain on (sub)components, such as heat sinks. Lumileds, therefore, recommends the following precautions when designing your application:

- When designing secondary lenses to be used over an LED, provide a sufficiently large air-pocket and allow for "ventilation" of this air away from the immediate vicinity of the LED.
- Use mechanical means of attaching lenses and circuit boards as much as possible. When using adhesives, potting compounds and coatings, carefully analyze its material composition and do thorough testing of the entire fixture under High Temperature over Life (HTOL) conditions.

Table 4. List of commonly used chemicals that will damage the silicone overcoat of LUXEON Z UV. Avoid using any of these chemicals in the housing that contains the LED package.

CHEMICAL NAME	NORMALLY USED AS
Hydrochloric acid	acid
Sulfuric acid	acid
Nitric acid	acid
Acetic acid	acid
Sodium hydroxide	alkali
Potassium hydroxide	alkali
Ammonia	alkali
MEK (Methyl Ethyl Ketone)	solvent
MIBK (Methyl Isobutyl Ketone)	solvent
Toluene	solvent
Xylene	solvent
Benzene	solvent
Gasoline	solvent
Mineral spirits	solvent
Dichloromethane	solvent
Tetracholorometane	solvent
Castor oil	oil
Lard	oil
Linseed oil	oil
Petroleum	oil
Silicone oil	oil
Halogenated hydrocarbons (containing F, Cl, Br elements)	misc
Rosin flux	solder flux
Acrylic tape	adhesive

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About Lumileds

Lumileds is the light engine leader, delivering innovation, quality and reliability.

For 100 years, Lumileds commitment to innovation has helped customers pioneer breakthrough products in the automotive, consumer and illumination markets.

Lumileds is shaping the future of light with our LEDs and automotive lamps, and helping our customers illuminate how people see the world around them.

To learn more about our portfolio of light engines, visit lumileds.com.

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