

# LUXEON Z

## Assembly and Handling Information

### Introduction

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

### Scope

The assembly and handling guidelines in this application brief apply to the following products:

- LUXEON Z White (LXZI-4070)
- LUXEON Z Green (LXZI-PM01)
- LUXEON Z Cyan (LXZI-PE01)
- LUXEON Z Blue (LXZI-PB01)
- LUXEON Z Royal Blue (LXZI-PR01)
- LUXEON Z Deep Red (LXZI-PA01)
- LUXEON Z Red (LXZI-PD01)
- LUXEON Z Red-Orange (LXZI-PH01)
- LUXEON Z Amber (LXZI-PL01)

In the remainder of this document the term LUXEON Z refers to any product in the LUXEON Z product family.

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# I. Component

## I.1 Description

The LUXEON Z emitter is an ultra-compact, surface mount, high-power direct color or white LED. Each LUXEON Z emitter consists of a high brightness InGaN or AlInGaP LED 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 emitter is marked with a small notch in the center of the electrode (see Figure 1).

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

All InGaN LUXEON Z emitters contain a transient voltage suppressor (TVS) chip which protects the LED chip against electrostatic discharge (ESD) events. The TVS chip creates some minor topographical variations across the top surface of the InGaN LUXEON Z emitters; all AlInGaP LUXEON Z emitters have a flat top surface.

The LUXEON Z emitter comes in three different form-factors, depending on the targeted color (see Figure 2):

1. White (InGaN LED chip): the nominal height is 0.69mm from the bottom of the electrodes to the top of the TVS.
2. Royal Blue, Blue, Green, Cyan (InGaN LED chip): the nominal height is 0.66mm from the bottom of the electrodes to the top of the TVS.
3. Amber, Red-Orange, Red, Deep Red (AlInGaP LED chip): all AlInGaP emitters are covered by a flat silicone overmold which protects the bond wire between the LED chip and the cathode. The nominal height is 0.96mm from the bottom of the electrodes to the top of silicone overmold.

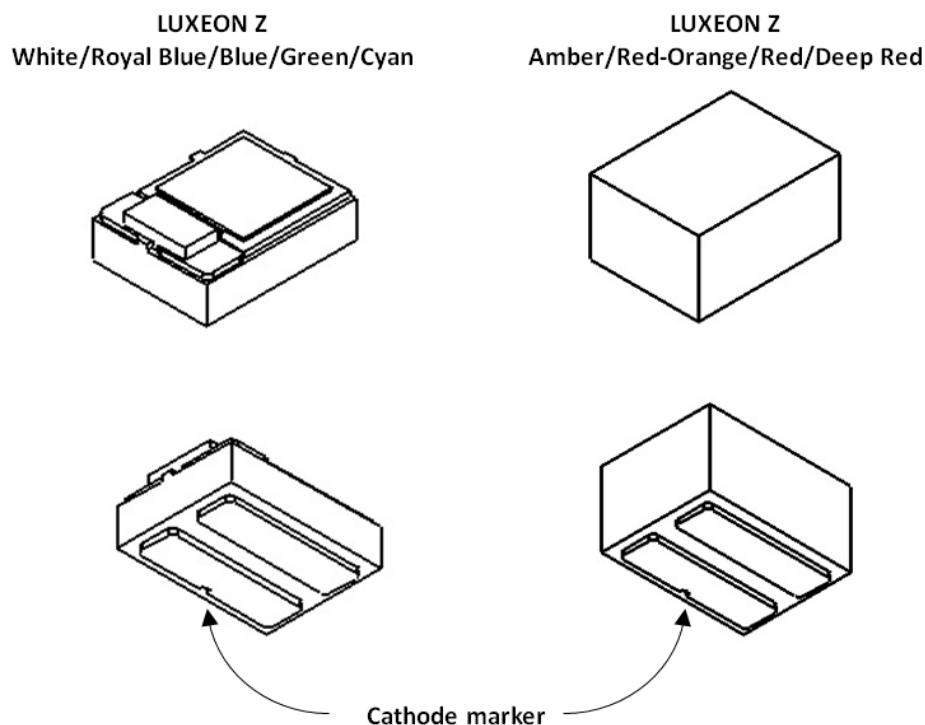
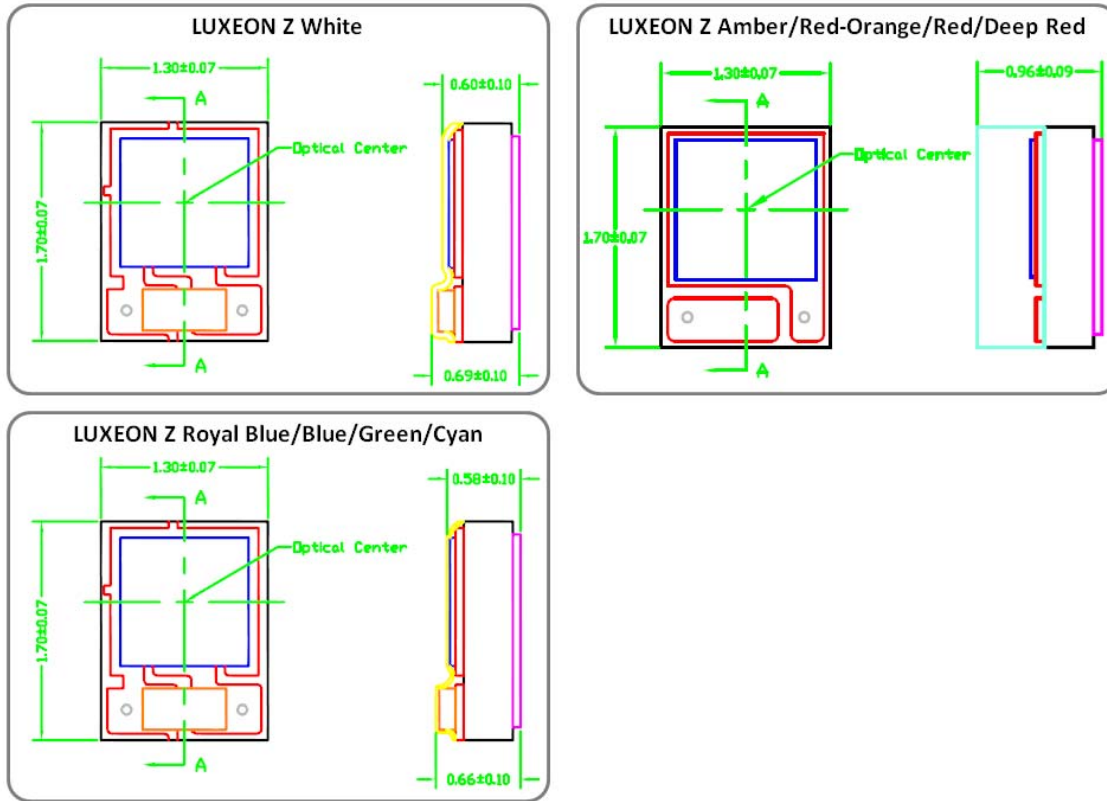


Figure 1. 3D renditions of LUXEON Z with InGaN chip (left) and AlInGaP chip (right).



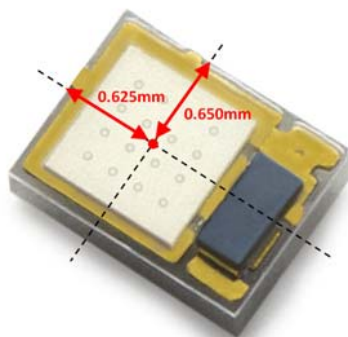
**Figure 2.** The LUXEON Z emitter comes in three different form factors, depending on the targeted color. All dimensions in mm.

## 1.2 Optical Center

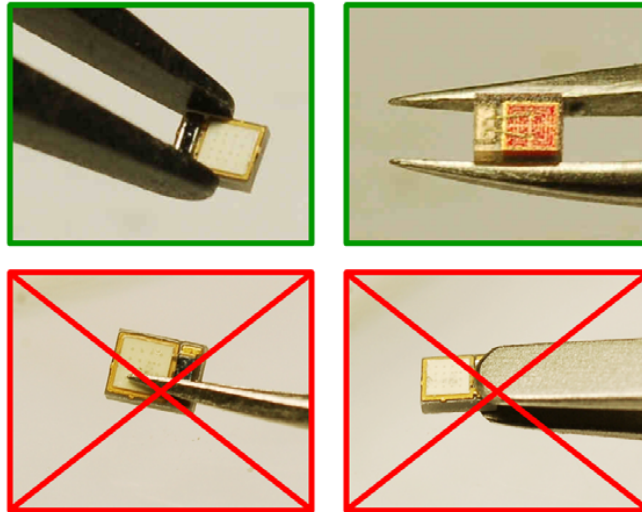
The theoretical optical center of the LUXEON Z emitter is 0.625mm from the top and 0.650mm from the side edges of the ceramic substrate (see Figure 3).

## 1.3 Handling Precautions

The LUXEON Z 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 emitters should only be picked up manually from the side of the ceramic substrate as shown in Figure 4.



**Figure 3.** The optical center of the LUXEON Z emitter is 0.625mm from the top and 0.650mm from the side edges.



**Figure 4. Correct handling (top) and incorrect handling (bottom) of LUXEON Z emitters.**

When handling finished boards containing LUXEON Z emitters, do not touch the top surface with any fingers (see Figure 5a) or apply any pressure to it. Also, do not 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 5b). A rough or contaminated surface, which is placed on top of a LUXEON Z emitter, may damage the silicone overcoat of the emitter. Furthermore, any pressure applied onto the LUXEON Z emitter during probing may damage the silicone layer or the chip underneath.

#### **1.4 Cleaning**

The LUXEON Z 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 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.

#### **1.5 Electrical Isolation**

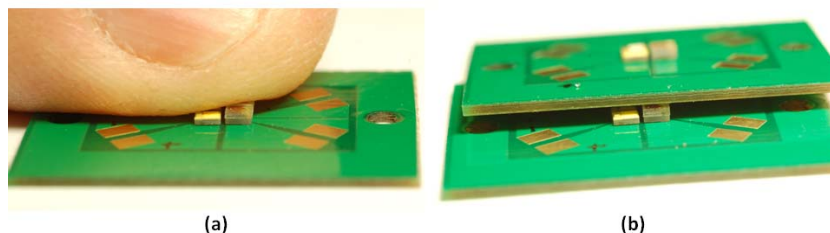
The LUXEON Z emitter contains only two electrical pads on the bottom of the ceramic substrate with a spacing of 0.25mm between them. In order to avoid any electrical shocks and/or damage to the LUXEON Z emitter, each design needs to comply with the appropriate standards of safety and isolation distances,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

#### **1.6 Mechanical Files**

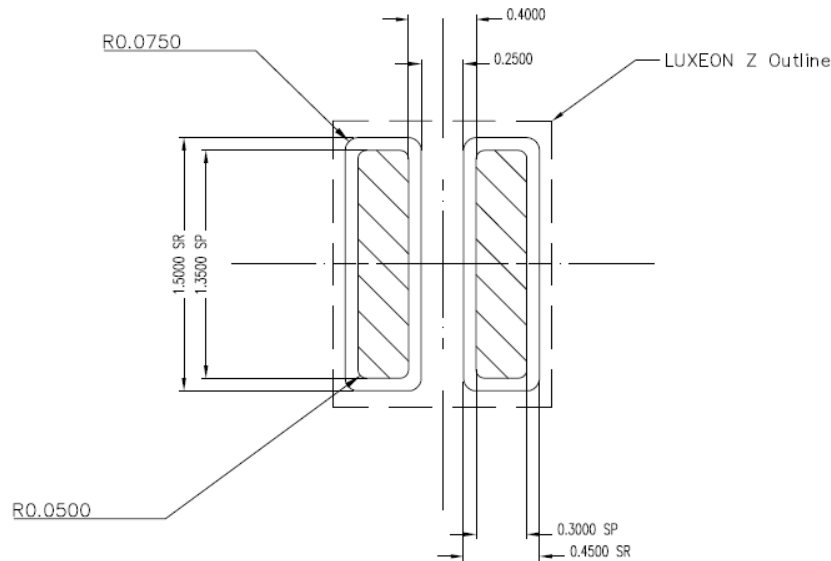
Mechanical drawings for LUXEON Z (2D and 3D) are available upon request.

#### **1.7 Soldering**

LUXEON Z emitters are designed to be soldered onto a Printed Circuit Board (PCB). For detailed assembly instructions, see Section 2.



**Figure 5. Do not touch the top of surface of the LUXEON Z emitter when handling a finished board (a) or stack boards with one or more LUXEON Z emitters on top of each other (b).**



**Figure 6. Recommended PCB Footprint for LUXEON Z. SR denotes solder resist opening and SP denotes stencil pattern.**

**All dimensions in mm.**

## 2. LUXEON Z Printed Circuit Board Design Rules

The LUXEON Z emitter is designed to be soldered onto a Metal Core PCB (MCPCB) or a multi-layer FR4 PCB. To ensure optimal operation of the LUXEON Z emitter, the PCB should be designed to minimize the overall thermal resistance between the LED package and the heat sink.

### 2.1 LUXEON Z Footprint and Land Pattern

The LUXEON Z emitter has two pads that need to be soldered onto corresponding pads on a PCB to ensure proper electrical operation. Figure 6 shows the minimum footprint design for a single LUXEON Z emitter in an application where multiple LUXEON Z emitters are placed in a densely packed array, with each emitter electrically addressable.

The electrical pads of the LUXEON Z emitter also serve as thermal pads between the LED and the PCB. To enhance heat dissipation from the LUXEON Z emitter into the PCB, it is best to extend the copper area around each electrode approximately 4mm from the center of the LUXEON Z 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 emitter approximately equal to ensure a balanced heat transfer from the LUXEON Z emitter through both electrodes.

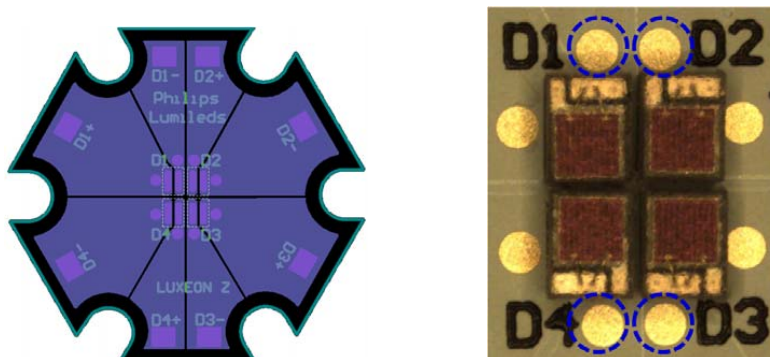
Figure 7 shows an example of a densely packed 2x2 LUXEON Z array on a metal core starboard. The spacing between the four LUXEON Z emitters (labeled D1 through D4) is 0.2mm. The pink areas in the drawing represent solder mask openings while the white dotted lines correspond to the outlines of the four LUXEON Z packages. The drawing of this starboard is available upon request.

### 2.2 Surface Finishing

Philips Lumileds recommends using a high temperature organic solderability preservative (OSP) on the copper layer.

### 2.3 Minimum Spacing

Philips Lumileds recommends a minimum edge to edge spacing between LUXEON Z emitters of 0.2mm. Placing multiple LUXEON Z emitters too close to each other may adversely impact the ability of the PCB to dissipate the heat from the emitters. Also, the light output for each LED may drop due to optical absorption by adjacent LED packages.



**Figure 7. A closely packed 2x2 LUXEON Z array configuration on a metal core PCB (left). Zoomed-in image of four LUXEON Z Red (AlInGaP) emitters mounted on the board (right). The pads marked with the dashed circles correspond to the preferred  $T_s$  measurement points for this configuration.**

### 3. Thermal Measurement Guidelines

This section provides general guidelines on how to determine the junction temperature of a LUXEON Z emitter in a stand-alone or 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 is specified in the LUXEON Z datasheet. In LUXEON Z, 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 emitter and  $T_{\text{thermal pad}}$  is the temperature at the bottom of one of the LUXEON Z electrodes, assuming both LUXEON Z electrodes are connected to copper pads on the PCB with approximately the same thermal resistance.

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 junction temperature is by measuring the temperature  $T_s$  of a predetermined sensor pad on the PCB right next to the LUXEON Z emitter with a thermocouple. To ensure accurate readings, the thermocouple must make direct contact with the copper of the PCB onto which the LUXEON Z electrode pads are soldered, i.e. any solder mask or other masking layer must be first removed before mounting the thermocouple onto the PCB.

The LUXEON Z emitter is ideally suited for applications where multiple color LEDs need to be placed in a closely packed array configuration. To mimic this scenario, Philips Lumileds built a 2x2 densely packed array configuration (see Figure 7). Given the asymmetry in the copper pads on the PCB, there are several candidate sensor pad locations around the 2x2 array configuration. The most appropriate  $T_s$  point depends, to a large extent, on the type of LUXEON Z emitters used and the operating conditions of the emitter array. The following guidelines help determine the most appropriate  $T_s$  location in a densely packed array application in order to approximate the maximum junction temperature in the LUXEON Z emitter array:

- If there is no symmetry in the copper layout of the PCB, it is best to place the  $T_s$  point next to the electrical pad (anode or cathode) where lateral heat spreading into the PCB is most impeded. This is typically the electrode with the least amount of copper. For example, in the closely packed 4-up configuration of Figure 7, the circular pads on the D1-, D2+, D3- and D4+ electrodes are preferred.

- b. If multiple LUXEON Z emitters of the same color are used, select the pad next to the LUXEON Z emitter with the highest nominal forward voltage (Vf).
- c. If a mixture of InGaN and AlInGaP LUXEON Z emitters is operated at approximately the same drive current, it is preferred to measure the pad temperature of the LUXEON Z AlInGaP emitter with the lowest wavelength and the LUXEON Z InGaN emitter with the highest wavelength. In this ranking according to wavelength, a LUXEON Z white emitter falls somewhere between a LUXEON Z Royal Blue and LUXEON Z Cyan emitter. The highest observed temperature should then be used to approximate the junction temperature.
- d. If different drive currents are used for each LUXEON Z emitter, it is generally best to measure the temperature next to the LUXEON Z emitter which consumes the most amount of electrical power.

The thermal resistance  $R\theta_{j-s}$  between the LUXEON Z junction and  $T_s$  point was experimentally determined to be approximately 5K/W for a densely packed 2x2 array of LUXEON Z emitters of the same color on a 1.0mm thick Al-MCPCB board (1oz copper with 4 mil thick Arlon 92ML dielectric layer). The spacing between the LUXEON Z emitters was 200µm. During these thermal measurements all four LUXEON Z emitters were powered to take into account any thermal crowding effects due to the close packing of the emitters. The junction temperature can then be calculated as follows:

$$T_j = T_s + 5 \cdot P_{\text{electrical\_array}} \text{ (assuming all 4 LEDs are powered)}$$

In this equation  $P_{\text{electrical\_array}}$  is the combined electrical power going into the four LUXEON Z emitters. The  $R\theta_{j-s}$  will typically be a bit lower if:

- the spacing between LUXEON Z emitters is increased
- the thickness of the top copper foil of the PCB is increased
- the thickness of the dielectric layer between the top copper foil and metal core is decreased
- the thermal conductivity of the dielectric material is increased.

The thermal resistance  $R\theta_{j-s}$  between the junction of a single (powered) LUXEON Z emitter and  $T_s$  point on the same 4-up board configuration of Figure 7 was experimentally determined to be 18K/W. The junction temperature for the single LUXEON Z emitter can then be calculated as follows:

$$T_j = T_s + 18 \cdot P_{\text{electrical}} \text{ (assuming a single emitter is powered only)}$$

LED board configurations with a larger number of closely packed LUXEON Z emitters may require additional thermal modeling to determine the pad temperature of those LUXEON Z emitters in the center of the array which are not easily accessible.

## 4. Assembly Process Guidelines

### 4.1 Stencil Design

The appropriate stencil design for the LUXEON Z emitter is included in the PCB footprint design (see Figure 6). The recommended stencil thickness is 125µm. The slightly smaller stencil pattern, compared to the solder resist opening, prevents the solder paste from accidentally bridging between the electrodes, which are only spaced 250µm apart.

### 4.2 Pick-and-Place

Automated pick and place equipment provides the best handling and placement accuracy for LUXEON Z emitters. Figure 8 and Figure 9 show two pick and place nozzle designs and corresponding machine settings which were successfully used for the various LUXEON Z configurations with pick and place equipment from Yamaha (YVI00X) and Juki (KE2080L). Based on these pick and place experiments, Philips advises customers to take the following general pick and place guidelines into account:



1. For LUXEON Z InGaN emitters, the tip of the nozzle should be positioned on the flat surface above the LED chip area; the area around the TVS should be avoided because of the height differences (see Figure 10). There is no such constraint on the nozzle position for LUXEON Z AllnGaP emitters.
2. The nozzle tip should be clean and free of any particles since this may interact with the silicone coating of the LUXEON Z package during pick and place.
3. During setup and any initial production runs, it is a good practice to inspect the top surface of the LUXEON Z emitters under a microscope to ensure the emitters are not accidentally damaged by the pick and place nozzle.

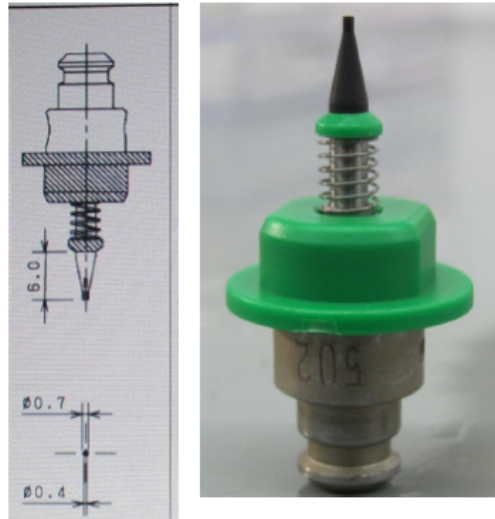
#### Standard off-the-shelf nozzle "7WA"



Pick and Mount Information		Vision Information	
Pick timer	0s	Alignment group	Special
Mount timer	0s	Alignment type	Odd.Chip
Pick height		Alignment module	Fore & Back & Las
InGaN (White)	0.28mm	Light selection	Main + Coax
InGaN (Direct Color)	0.30mm	Lighting level	5/8
AllnGaP	0.19mm	Comp. threshold	91
Mount height	0mm	Comp. tolerance	15
Mount action	Normal	Search area	1.5mm
Mount speed	100%	Comp. intensity	N/A
Pickup speed	100%	Auto threshold	Not Used
Vacuum Check	Normal Chk		
Pick Vacuum	20%		
Mount vacuum			
InGaN	60%		
AllnGaP	90%		

**Figure 8. Pick and place nozzle design and corresponding machine settings for Yamaha YV100X in combination with the off-the-shelf nozzle 7WA.**  
**Note that some of the machine settings are unique to each LUXEON Z configuration.**

Standard off-the-shelf nozzle "502"



Pick and Mount Information		Vision Information	
XY	Fast2	Centering method	Laser
Pick depth	0mm	Comp shape	Corner Square
Picking stroke	0mm		
Pick Z down	Fast2		
Pick Z up	Fast2		
Placing stroke	0mm		
Place Z down	Fast2		
Place Z up	Fast2		
Theta (measure)	Fast		
Theta (other)	Fast		

**Figure 9: 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 for all LUXEON Z configurations.**

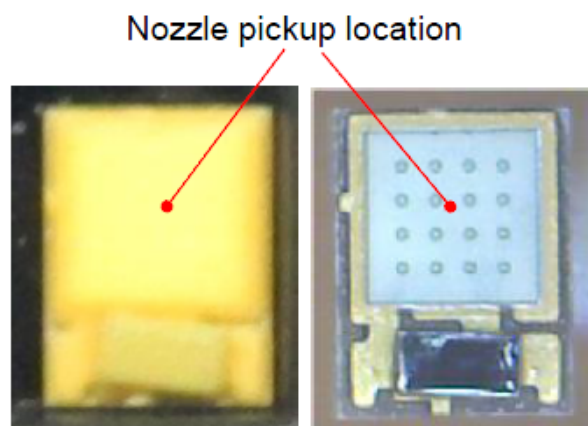


Figure 10. Nozzle pick-up location for LUXEON Z (InGaN) emitters.

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

Since the LUXEON Z emitter has no primary optics or lens which can act as a mechanical enclosure protection for the LED chip, the pick-up and placement force applied to the top of the package should be kept to a minimum. This is particularly important for LUXEON Z InGaN direct color and LUXEON Z white emitters in which the silicone layer (with phosphor – for white emitters) is about 25 $\mu$ m and 50 $\mu$ m thick, respectively. The LUXEON Z AlInGaP emitters, in contrast, have a much thicker silicone layer and are, therefore, able to absorb higher forces. Experimental studies with various pick and place machines confirmed that LUXEON Z emitters can be reliably picked from tape and placed onto a PCB with a placement force  $\leq 30$ grams. Note that this 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.

### 4.3 Reflow Accuracy

Using the solder resist and stencil pattern layout as shown in Figure 6, Philips Lumileds has determined the placement accuracy after reflow to be within a standard deviation of 24 $\mu$ m in the x and y direction. For a small and lightweight package like LUXEON Z, the surface tension of liquid solder is typically sufficient to realign the LUXEON Z package to the nominal position of the footprint layout as demonstrated in Figure 11.

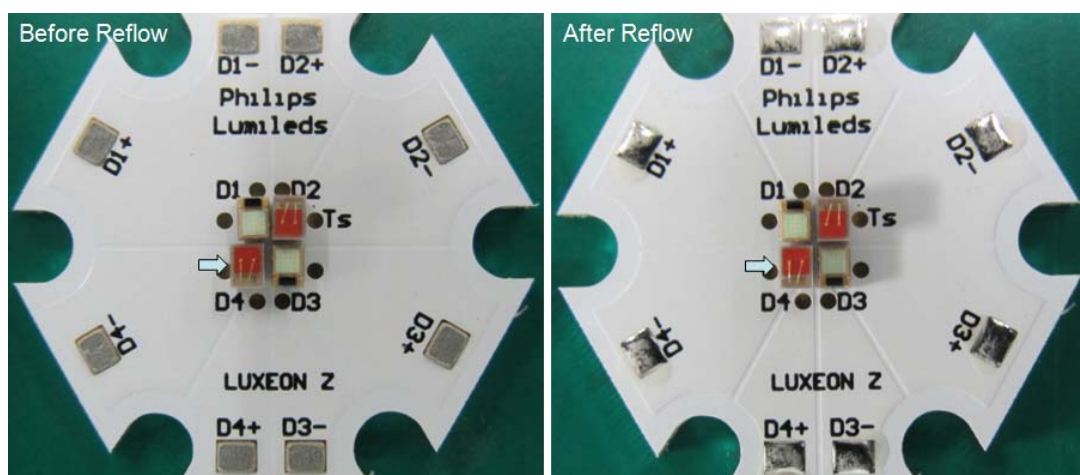


Figure 11. LUXEON Z self alignment before (left) and after reflow (right).

## 5. Packaging Considerations – Chemical Compatibility

The LUXEON Z 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 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 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 “blue” 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.

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

The chemicals in Table I are typically not directly used in the final products that are built around LUXEON Z 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. Philips 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 1. List of commonly used chemicals that will damage the silicone overcoat of LUXEON Z.  
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
tetrachlorometane	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

# Company Information

Philips Lumileds is a leading provider of LEDs for everyday lighting applications. The company's records for light output, efficacy and thermal management are direct results of the ongoing commitment to advancing solid-state lighting technology and enabling lighting solutions that are more environmentally friendly, help reduce CO<sub>2</sub> emissions and reduce the need for power plant expansion. Philips Lumileds LUXEON® LEDs are enabling never before possible applications in outdoor lighting, shop lighting, home lighting, consumer electronics, and automotive lighting.

Philips Lumileds is a fully integrated supplier, producing core LED material in all three base colors, (Red, Green, Blue) and white. Philips Lumileds has R&D centers in San Jose, California and in the Netherlands, and production capabilities in San Jose, Singapore and Penang, Malaysia. Founded in 1999, Philips Lumileds is the high flux LED technology leader and is dedicated to bridging the gap between solid-state technology and the lighting world. More information about the company's LUXEON LED products and solid-state lighting technologies can be found at [www.philipslumileds.com](http://www.philipslumileds.com).

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