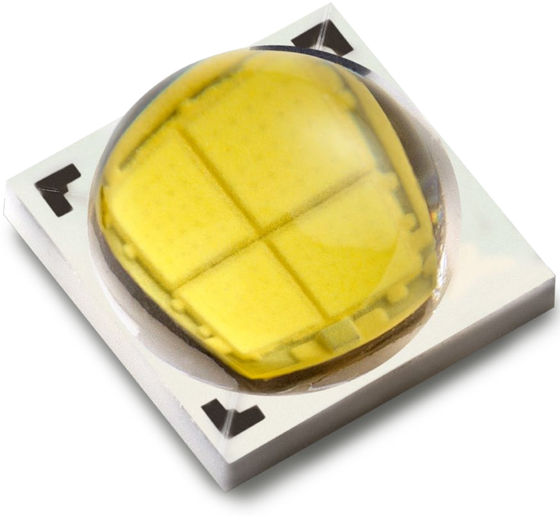


LUXEON M
Assembly and Handling
Information

Application Brief AB103

LUXEON M

Assembly and Handling Information

Introduction

This application brief addresses the recommended assembly and handling procedures for LUXEON® M emitters. LUXEON M emitters are designed to deliver high luminous flux and efficacy from a compact optical source in order to enable a wide range of outdoor and industrial lighting applications. Proper assembly, handling, and thermal management, as outlined in this application brief, ensure high optical output and long lumen maintenance for LUXEON M emitters.

Scope

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

- LUXEON M 4000K (LXR7-SW40)
- LUXEON M 5700K (LXR7-SW57)

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

Table of Contents

1. Component

1.1 Description

The LUXEON M emitter consists of a 2x2 LED chip array mounted onto a ceramic substrate. This substrate provides mechanical support and thermally connects the LED chips to a thermal pad on the bottom of the substrate. An electrical interconnect layer connects the LED chips to a cathode and anode on the bottom of the ceramic substrate. The ceramic substrate is surrounded by a larger ceramic frame and is overmolded with a silicone dome to enhance light extraction and to shield the chip array from the environment. Each LUXEON M emitter includes a transient voltage suppressor (TVS) chip under the silicone dome to protect the emitter against electrostatic discharges (ESD).

The bottom of the LUXEON M emitter (Figure 1) contains four metallization pads, a large thermal pad in the center, an anode, a cathode, and a small pad with a laser engraved LED serial number. The pad with the serial number is not designed to be soldered onto a PCB.

Each LUXEON M emitter contains three staircase-style fiducials on the ceramic frame outside the dome (see the top view of LUXEON M in Figure 1). In order to identify the anode and cathode, rotate the LUXEON M emitter so that the three fiducials are on the top left, bottom left, and top right corner of the ceramic substrate when viewed from above as shown in Figure 1. The left side, marked by the two fiducials in the top and bottom corner, then corresponds to the cathode side of the LUXEON M emitter. The anode side only contains one fiducial in the top corner, when viewed from above.

1.2 Optical Center

The LUXEON M emitter contains three feature sets to locate the theoretical optical center (see Figure 2):

1. Topside fiducials
   The fiducial marks on the ceramic frame of the LUXEON M emitter provide the most accurate methodology to locate the theoretical optical center. The theoretical optical center is located 3.14mm from the vertical and horizontal edges of each fiducial mark.
2. Backside metallization
   The optical center can be located using the edges of the thermal pad on the bottom of the ceramic substrate. The theoretical optical center is 1.08mm and 1.75mm from the long and short edge, respectively, of the thermal pad.
3. LED outline
   The theoretical optical center is located 3.50mm from the edge of the LUXEON M emitter.

Optical rayset data for LUXEON M is available upon request.

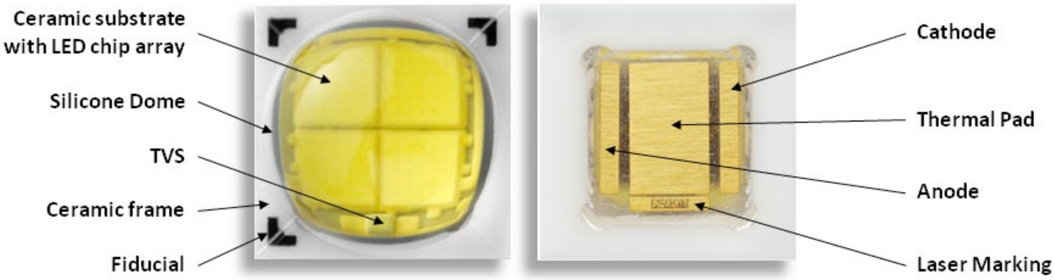
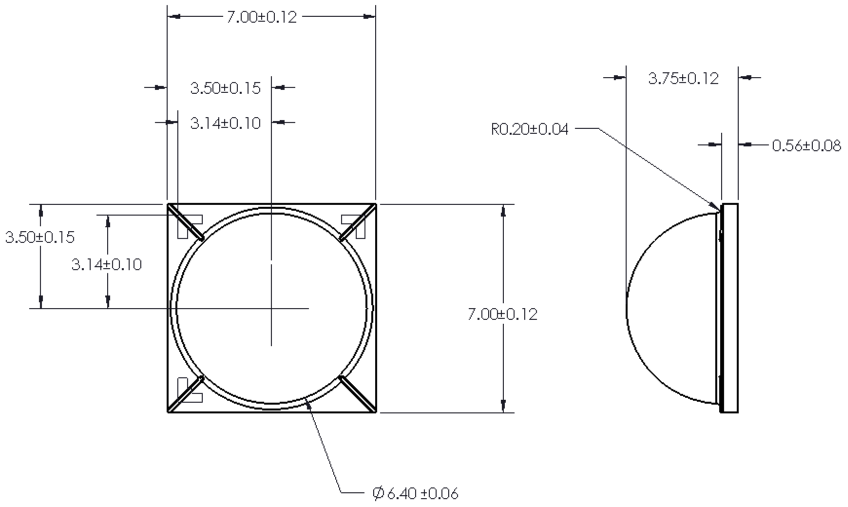


Figure 1. Top view (left) and bottom view (right) of LUXEON M emitter. The pad with the laser marking should not be soldered onto a PCB.



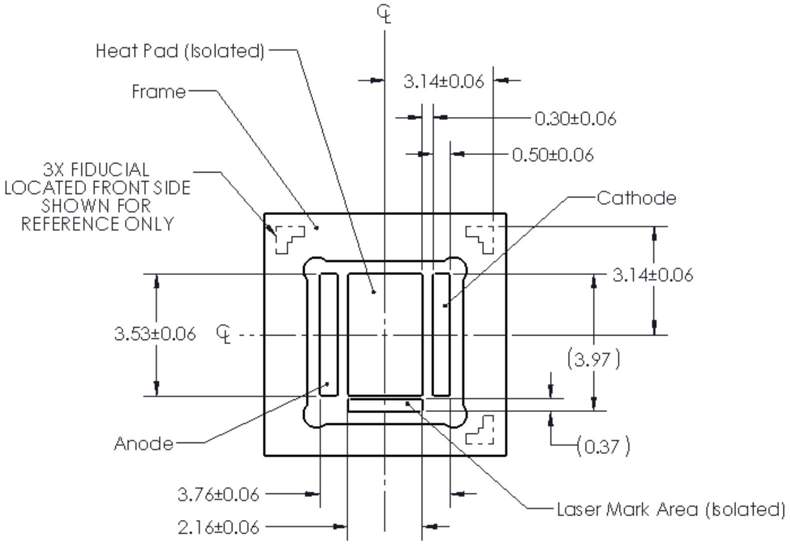


Figure 2. Fiducial marks on the top of the LUXEON M emitter provide the most accurate method to locate the theoretical optical center.

1.3 Handling Precautions

LUXEON M is designed to maximize light output and reliability. However, improper handling of the device may damage the silicone dome and affect the overall performance and reliability. In order to minimize the risk of damage to the silicone dome during handling, LUXEON M emitters should only be picked up from the side of the ceramic frame as shown in Figure 3.

1.4 Cleaning

LUXEON M should not be exposed to dust and debris. Excessive dust and debris may cause a drastic decrease in optical output. In the event that a LUXEON M emitter requires cleaning, first try a gentle swabbing using a lint-free swab. If needed, a lint-free swab and isopropyl alcohol (IPA) can be used to gently remove dirt from the lens. Do not use other solvents as they may adversely react with the LED assembly. For more information regarding chemical compatibility, see Section 6.

Figure 3. Incorrect handling (left and middle) and correct handling (right) of LUXEON M emitters.

1.5 Electrical Isolation

The thermal pad of the LUXEON M is electrically isolated from its cathode and anode. Consequently, a high voltage difference between electrical and thermal metallization may occur in applications where multiple LUXEON M emitters are connected in series. As a reference, the nominal distance between the electrical metallization and the thermal metallization of the LUXEON M emitter is 0.3mm.

In order to avoid any electrical shocks and/or damage to the LUXEON M 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 M (2D and 3D) are available upon request.

1.7 Soldering

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

2. LUXEON M Printed Circuit Board Design Rules

The LUXEON M 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 M emitter, the PCB should be designed to minimize the overall thermal resistance between the LED package and the heat sink.

2.1 LUXEON M Footprint and Land Pattern

The LUXEON M emitter has three pads that need to be soldered onto corresponding pads on the PCB to ensure proper thermal and electrical operation. The pad with the laser engraved serial number is not designed to be soldered onto the PCB. Figure 4 shows the recommended footprint design for the solder mask and the copper layout on a Metal Core PCB. Philips Lumileds recommends extending the thermal pad and electrodes at least 10mm from the center of the LUXEON M LED to maximize heat spreading into the PCB.

The recommended footprint design includes special fiducials near the corners of the LUXEON M to facilitate visual inspection of the placement accuracy of the LUXEON M emitter on the PCB board.

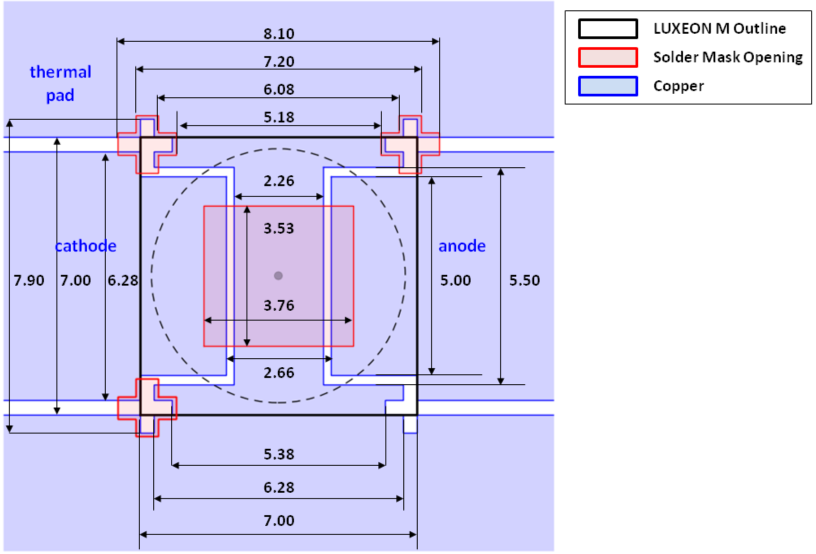


Figure 4. Recommended LUXEON M footprint design for Metal Core PCB. All dimensions in mm.

2.2 Surface Finishing

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

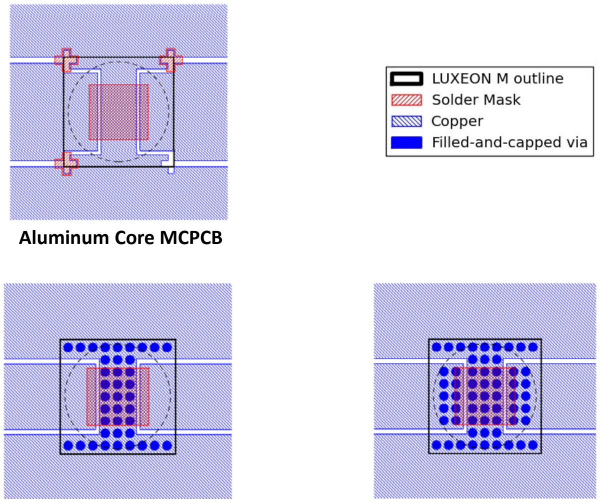
2.3 Minimum Spacing

Philips Lumileds recommends a minimum edge to edge spacing between LUXEON M emitters of 13mm. Placing multiple LUXEON M 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.

3. Thermal Management

The overall thermal resistance between the LUXEON M emitter and the heat sink is strongly affected by the design and material of the PCB on which the LUXEON M emitter is soldered. Metal Core PCBs have been historically used in the LED industry for their low thermal resistance and rigidity. However, MCPCBs may not always offer the most economical solution.

Multi-layer epoxy FR4 PCBs are commonly used in the electronics industry and can in certain LED applications yield a lower cost solution. Given the poor thermal conductivity of the epoxy in FR4 PCBs, it is important to include special thermal vias in the PCB design to aid the transport of heat from the LED to the heat sink on which the PCB is mounted. A thermal via is a plated through hole that can be open, plugged, filled or filled and capped. Open vias are typically placed outside the pads on which the LEDs are soldered to prevent any solder from reaching the other side during reflow. A filled-and-capped via, in contrast, can be placed directly underneath the thermal pad of the LED, improving the thermal performance of the PCB.



Aluminum Core MCPCB

FR4 with capped-and-filled vias (vias on thermal pad only)

FR4 with capped-and-filled vias (vias on thermal pad and electrodes)

Figure 5. Several LUXEON M PCB designs were simulated and/or experimentally measured to determine the typical thermal resistance between the thermal pad and the heat sink.

Philips Lumileds conducted a simulation study to determine the typical thermal resistance for various LUXEON M PCB designs. In addition, several PCB designs were manufactured and the thermal resistance was experimentally determined. The remainder of this section discusses the different PCB designs which were considered and compares the merits of each PCB design in terms of its overall thermal resistance between the LUXEON M emitter and the heat sink.

3.1 PCB designs for LUXEON M

The thermal resistance study for LUXEON M focused on several different PCB designs requiring different PCB manufacturing technologies (see Figure 5):

Metal Core PCB

The thermal simulation study focused on an MCPCB design with a 100µm dielectric layer and a 70µm (2oz) copper foil. The thermal conductivity of the dielectric material in the simulation study is assumed to be 1Wm-1K-1. In addition, several MCPBCs were manufactured. Each MCPCB contained an 80µm thick dielectric layer with a thermal conductivity of 2.7Wm-1K-1 and a copper foil thickness of 35µm (1oz) or 70µm (2oz). In order to assess the impact of the metal substrate on the overall thermal resistance, both aluminum core and copper core MCPCB designs were evaluated.

FR4 PCB with filled-and-capped vias

The thermal simulation study included two FR4 PCB designs with filled-and-capped vias. The FR4 epoxy board in each design is assumed to be 0.8mm thick and has a glass fiber content of 25%. Copper foils with a thickness of 70µm (2oz) copper foils are attached to both sides. The metallization patterns on top and bottom of the PCBs are assumed to be identical. The filled-and-capped vias have a diameter of 0.5mm, are plated with 25µm copper, and are filled with epoxy afterwards. The pitch between the filled-and-capped vias is 0.75mm. The first design in this category contains filled-and-capped vias in the thermal pad only. The second design has additional filled-and-capped vias on the electrodes as well.

Table 1. Rθ values between LUXEON M thermal pad and heat sink for various PCB designs.

PCB Technology	Details	Cu-foil	$R\theta_{\text{pad-heat sink}}$ [K/W]
Al-core MCPCB	80µm dielectric (2.7$Wm^{-1}K^{-1}$)	70µm (2oz)	1.8
Al-core MCPCB	80µm dielectric (2.7$Wm^{-1}K^{-1}$)	35µm (1oz)	2.9
Al-core MCPCB	100µm dielectric (1.0$Wm^{-1}K^{-1}$)	70µm (2oz)	3.3
Cu-core MCPCB	80µm dielectric (2.7$Wm^{-1}K^{-1}$)	35µm (1oz)	2.3
Cu-core MCPCB	100µm dielectric (1.0$Wm^{-1}K^{-1}$)	70µm (2oz)	3.2
FR4 (filled-and-capped vias)	Vias on thermal pad only	70µm (2oz)	5.3
FR4 (filled-and-capped vias)	Vias on thermal pad and electrodes	70µm (2oz)	3.7

The filled-and-capped vias in these FR4 designs create an electrical path between the top and bottom metallization layers of the PCB. Therefore, an additional Thermal Interface Material (TIM) is required between the FR4 PCB and heat sink to ensure sufficient electrical shielding between the traces on the FR4 PCB and the heat sink. In order to provide a fair comparison between the different board designs in this study, a 0.1mm TIM layer with a thermal conductivity 1$Wm^{-1}K^{-1}$ is included in all thermal simulations of the filled-and-capped FR4 designs.

3.2 Thermal Resistance Results

Table 1 summarizes the thermal resistance values between the heat sink and the LUXEON M thermal pad for the various PCB designs considered in this study. These results suggest that the typical thermal resistance of a properly designed MCPCB is somewhere between 2.0K/W and 3.5K/W, depending on the quality and thickness of the materials used. In contrast, an FR4 PCB with filled-and-capped thermal vias yields a thermal resistance between 3.5K/W and 5.5K/W.

For completeness, several FR4 PCB designs with open vias were also considered in this study. However, both experimental and simulation results indicate that the typical thermal resistance for these designs is above 6.5K/W.

Simulation and experimental results indicate that the thermal resistance of an MCPCB can be reduced to well below 2K/W if the dielectric material between the LUXEON M thermal pad and the core of the MCPCB is eliminated. This approach can be particularly useful in certain high-density applications where multiple LUXEON M LEDs are placed in close proximity to each other.

4. Thermal Measurement Guidelines

The typical thermal resistance $R\theta_{(\text{j-thermal pad})}$ between the junction and thermal pad for LUXEON M is 1.25K/W. With this information, the junction temperature T_j can be easily determined according to the following equation:

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

In this equation $T_{\text{thermal pad}}$ is the temperature at the bottom of the LUXEON M thermal pad and $P_{\text{electrical}}$ is the electrical power going into the LUXEON M emitter.

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 M junction temperature is by measuring the temperature T_s of a predetermined sensor pad on the PCB right next to the LUXEON M emitter with a thermocouple (see Figure 6). The recommended location of the sensor pad is 0.5mm from the edge of the LUXEON M emitter, on the center line between anode and cathode. The thermocouple must make direct contact with the copper of the PCB onto which the LUXEON M thermal pad is soldered, i.e. any solder mask must be first removed before mounting the thermocouple onto the PCB.

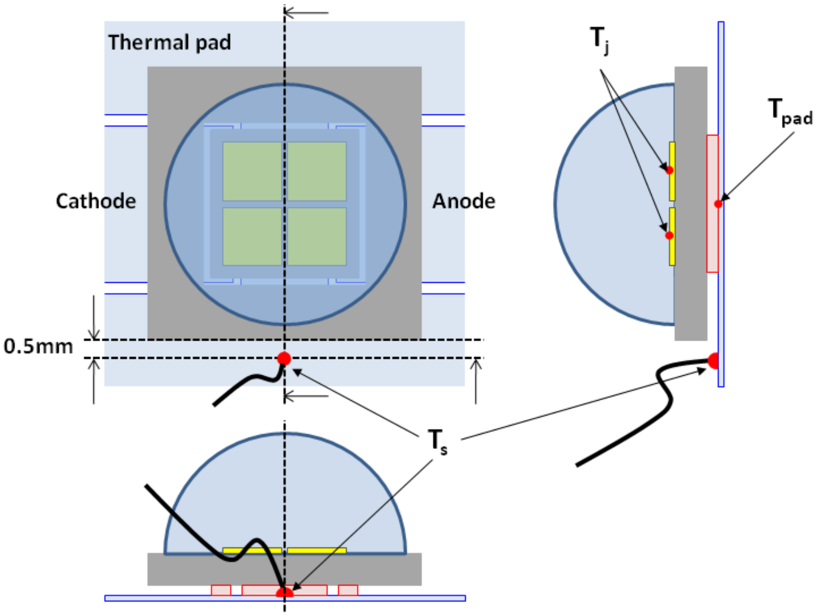


Figure 6. The recommended temperature measurement point Ts is located next to the LUXEON M emitter on the thermal pad of the PCB.

The thermal resistance $R\theta_{j\text{-}s}$ between the sensor pad and the LUXEON M junction was experimentally determined to be approximately 3.0K/W on a MCPCB. The junction temperature can then be calculated as follows:

$$T_j = T_s + 3.0 \bullet P_{electrical}$$

5. Assembly Process Guidelines

5.1 Stencil Design

Figure 7 shows the recommended stencil design for LUXEON M. The recommended stencil thickness is 125µm.

5.2 Solder Paste

Philips Lumileds recommends lead-free solder for the LUXEON M emitter. Philips Lumileds has successfully tested SAC305-OM338 from Alpha Metals with satisfactory results. However, since application environments vary widely, Philips Lumileds recommends that customers always perform their own solder paste evaluation in order to ensure it is suitable for the targeted application and operating conditions.

5.3 Pick-and-Place

Automated pick and place equipment provides the best placement accuracy for LUXEON M emitters. Figure 8 - Figure 12 show various pick and place nozzle designs and corresponding machine settings which were successfully used for LUXEON M emitters with pick and place equipment from Panasonic, Yamaha, Juki and Samsung. Each nozzle is designed to pick the LUXEON M emitter up from the flat area around the dome without making any contact with the silicone dome.

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

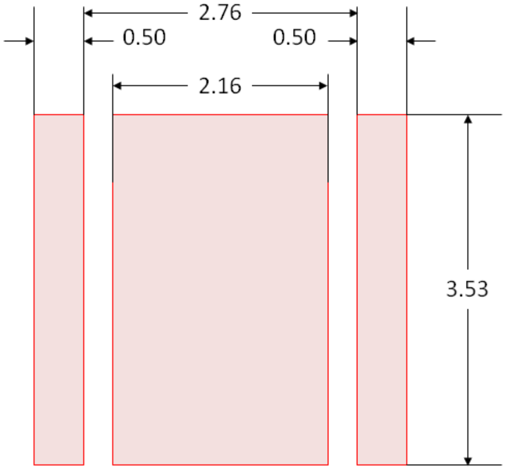
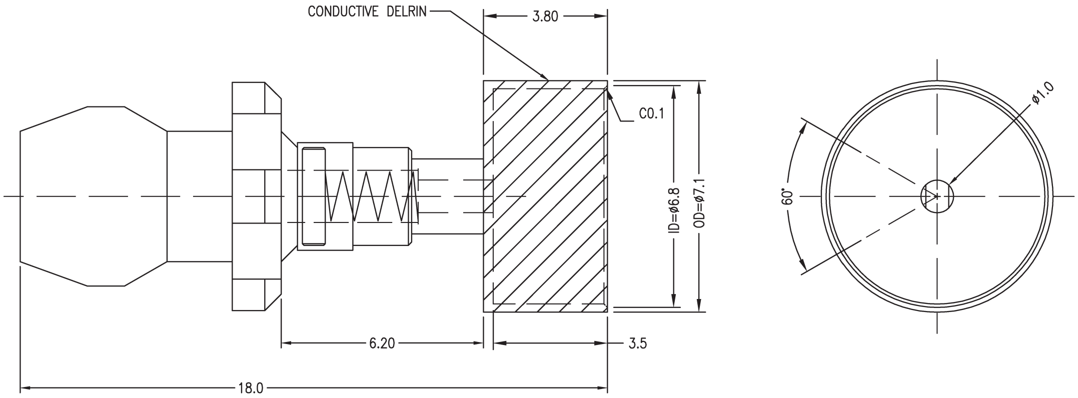
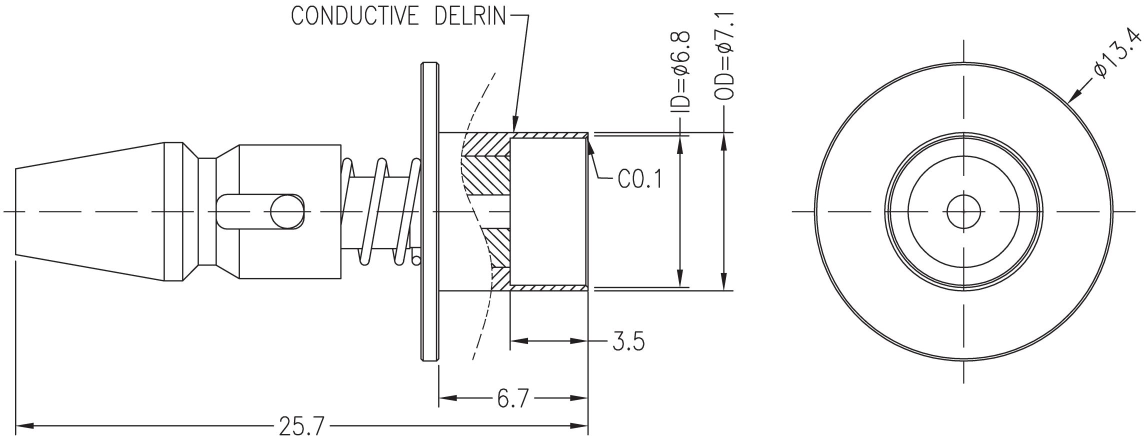


Figure 7. Recommended stencil design for LUXEON M. All dimensions in mm.



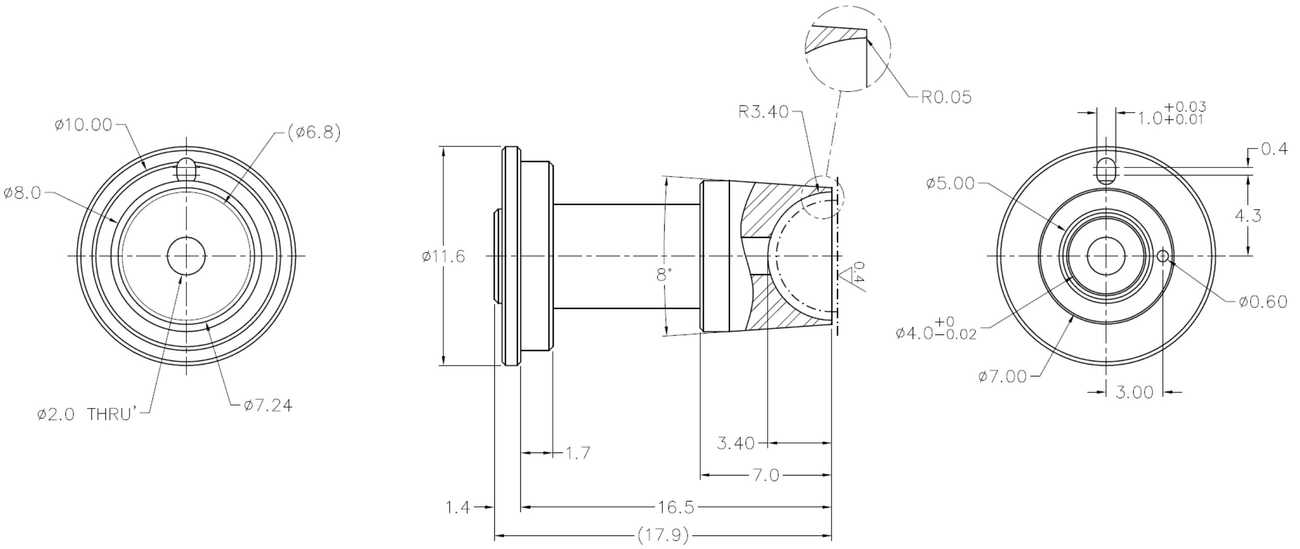
Pick and Mount Information		Vision Information	
Pick timer	0.3 s	Alignment group	Chip
Mount timer	0.3 s	Alignment type	Std.Chip
Pick height	2.5 mm	Alignment module	Fore & Back & Las
Mount height	-1.0 mm	Light selection	Main + Coax
Mount action	QFP	Lighting level	5/8
Mount speed	50%	Comp. threshold	30
Pickup speed	50%	Comp. tolerance	30
Vacuum Check	Normal Chk	Search area	0.8mm
Pick Vacuum	30%	Comp. intensity	116
Mount vacuum	50%	Auto threshold	Use

Figure 8. Pick and place nozzle design and machine settings for Yamaha YV100X. All dimensions in mm. Nozzle drawing courtesy of Ching Yi Technology Pte Ltd (part #:YMH-0078/12).



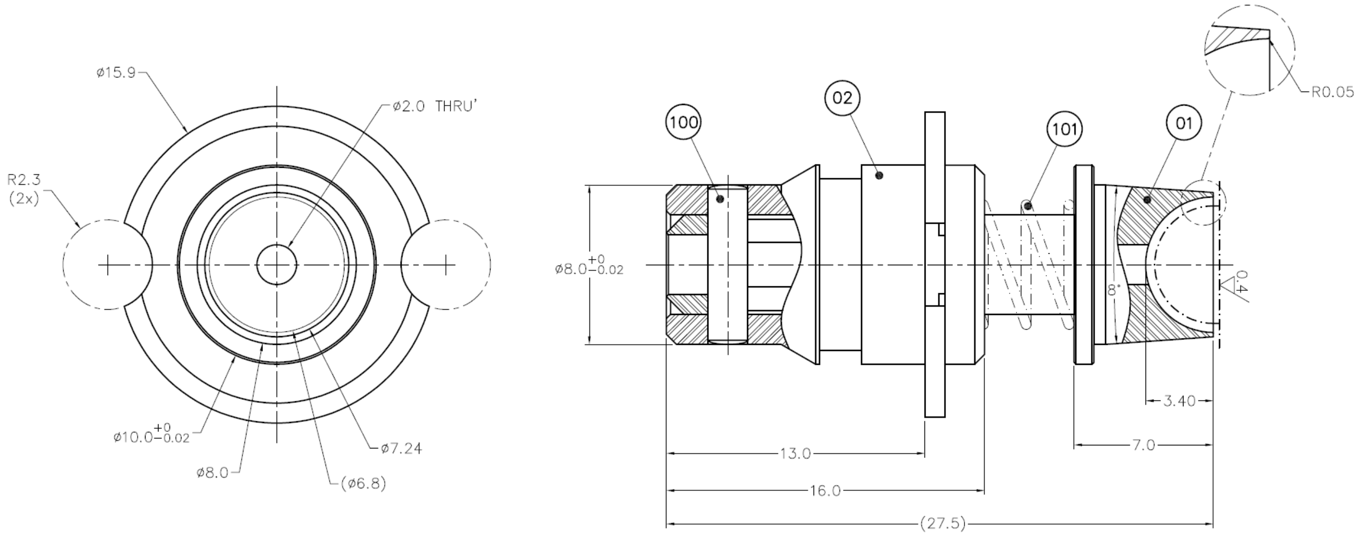
Pick and Mount Information		Vision Information	
Pick Height	-3.5 mm	Camera No	Fly Cam5
Mount Height	1 mm	Side	11
Delay – Pick Up	300 msec	Outer	8
Delay - Place	100 msec		
Delay - Vac Off	0		
Delay – Blow On	100 msec		
Speed – XY	2		
Speed – Z Pick Down	2		
Speed – Z Pick Up	2		
Speed – R	2		
Speed – Z Place Down	2		
Speed – Z Place Up	2		
Z Align Speed 2	2		
Soft Touch	Pick & Mount		
Mount Method	Normal		

Figure 9. Pick and place nozzle design and machine settings for Samsung SM421. All dimensions in mm. Nozzle drawing courtesy of Ching Yi Technology Pte Ltd. (part #: SAM-1313/11).



Pick and Mount Information		Vision Information	
XY speed	1	Camera	2D Large FOV
Theta speed	1	Upper L	0
Nozzle movement – pickup	1:	Middle L	1
	Descend 1 stroke	Lower L	3
	Ascend 1 stroke		
Nozzle movement – mount	1:		
	Descend 1 stroke		
	Ascend 1 stroke		
Pickup – height	0.6 mm		
Pickup – thickness	0.6 mm		
Pickup – depth	0 mm		
Pickup – height allowance	0 mm		
Pickup – height offset	- 3.0 mm		
Mount height	1.0 mm		

Figure 10. Pick and place nozzle design and machine settings for Panasonic BM221. All dimensions in mm. Nozzle drawing courtesy of Micro-Mechanics Pte Ltd (drawing #: 19-MT-10053-01).



Pick and Mount Information	
Placing stroke	1.0 mm
Picking stroke	2.5 mm
XY speed	Fast
Picking Z down	Fast
Picking Z up	Fast
Placing Z down	Fast
Placing Z up	Fast
Laser position	-0.11

Figure 11. Pick and place nozzle design and machine settings for Juki KE750. All dimensions in mm. Nozzle drawing courtesy of Micro-Mechanics Pte Ltd (drawing #: 19-MT-10043-01). A production pick and place machine will typically include a vision camera system to recognize the bottom pads of the package. However, the Juki KE750 pick and place machine used in this study is a dedicated test machine and did not include any vision camera system. Consequently, no detailed vision information is available for this machine.

5.4 Solder Reflow Profile

The LUXEON M emitter is compatible with standard surface-mount and lead-free reflow technologies. This greatly simplifies the manufacturing process by eliminating the need for adhesives and epoxies. The reflow step itself is the most critical step in the reflow soldering process and occurs when the boards move through the oven and the solder paste melts, forming the solder joints. To form good solder joints, the time and temperature profile throughout the reflow process must be well maintained.

A temperature profile consists of three primary phases:

1. Preheat: the board enters the reflow oven and is warmed up to a temperature lower than the melting point of the solder alloy.
2. Reflow: the board is heated to a peak temperature above the melting point of the solder, but below the temperature that would damage the components or the board.
3. Cool down: the board is cooled down, allowing the solder to freeze, before the board exits the oven.

As a point of reference, the melting temperature for SAC 305 is 217°C, and the minimum peak reflow temperature is 235°C. For detailed information on the recommended reflow profile, refer to the IPC/JEDEC J-STD-020C reflow profile in the LUXEON M datasheet.

5.5 Placement and Reflow Accuracy

In order to achieve the highest placement accuracy Philips Lumileds recommends using an automated pick and place tool with a vision system that can recognize the bottom metallization of the LUXEON M emitter.

Global fiducials on a PCB panel can be used to calculate the reflow accuracy of the LUXEON M emitter with respect to its theoretical board position. Philips Lumileds has determined that the typical placement accuracy of a LUXEON M emitter after reflow is well within 100µm in the x- and y-direction for the footprint in Figure 4.

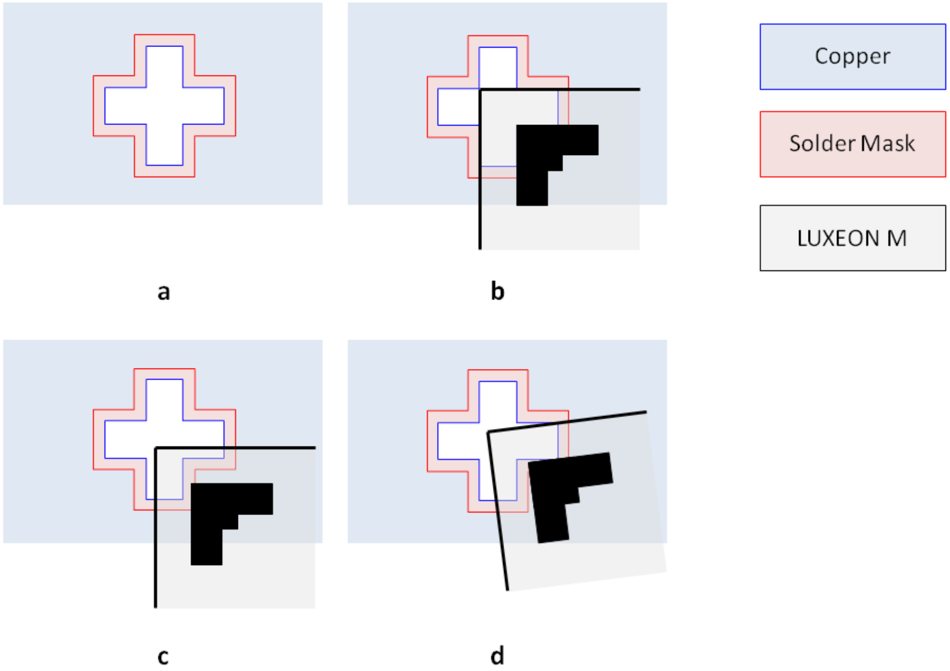


Figure 12. Alignment crosses on the PCB (a) help estimate the placement accuracy of the LUXEON M emitter on the PCB before and/or after reflow. The outer corner of the staircase style fiducials on the LUXEON M ceramic substrate align with the inner corner of the alignment crosses on the PCB for a properly placed LUXEON M emitter (b). Placement errors in x- and y-direction (c). Rotation errors in additions to placement errors in x- and y-direction (d).

The PCB design in Figure 4 contains three alignment crosses, which correspond to the location of the three staircase style fiducials on the ceramic substrate of the LUXEON M emitter (see Figure 1). These alignment features enable visual verification of the proper orientation of the LUXEON M on the PCB. In addition, these features help approximate the placement accuracy of the LUXEON M before and/or after reflow, see Figure 12.

5.6 JEDEC Moisture Sensitivity Levels

LUXEON M emitters have a JEDEC moisture sensitivity level of 1. This is the highest level offered in the industry and highest level within the JEDEC standard. This ensures ease of use since the user no longer needs to be concerned about bake out times and floor life.

6. Packaging Considerations—Chemical Compatibility

The LUXEON M package contains a silicone overcoat and dome to protect the LED chips and extract the maximum amount of light. 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 M 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 M 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 dome. Under heat and "blue" light, the VOCs inside the dome 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 dome 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 2 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 2 are typically not directly used in the final products that are built around LUXEON M 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 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 2. List of commonly used chemicals that will damage the silicone dome of LUXEON M. 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

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_2 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.

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