Light Emitting Diode

Design Considerations for Direct Mountable Chip LEDs (NxSxExxA) for High-Density Applications

Table of contents

The Nichia part numbers NxSxExxA, NCSxE17A, and NVSxE21A within this document are merely Nichia's part numbers for those Nichia products and are not related nor bear resemblance to any other company's product that might bear a trademark.

1. Overview

As a result of growing trends to reduce the size and increase the light energy of LED-based luminaries, the demand for compact, high luminous flux and high efficiency LEDs has been increasing. Since Nichia's NxSxExxA LEDs are smaller in size than other LEDs that produce the same amount of light energy, they are more suitable for high-density applications that require high brightness and high luminous flux. This document provides information on how the optical characteristics of the luminaire are affected when NxSxExxA LEDs are being used in a high-density application and what issues arise when heat is concentrated on the areas between the LEDs, as well as Nichia's evaluation results on these issues.

2. NxSxExxA LED Structure and Concerns about High-Density Mounting

NxSxExxA LEDs have a compact package and a structure that maximizes the luminous efficacy of the LED. The LED does not use a primary substrate (e.g. lead frame, etc.) for the electrical connection, so the face-down LED die is designed to be able to be soldered directly onto a secondary substrate. For the appearance of NxSxExxA LEDs, see Figure 1, and for the overview of the LED structure, see Figure 2.

Figure 1. NxSxExxA Appearance

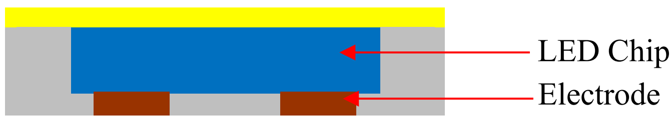


Figure 2. Internal Structure of NxSxExxA Series

In order to be able to meet variations in demand for the performance and/or design of the chosen application the NxSxExxA series has two options for the size (i.e. 2.1 x 2.1mm = NVSxE21A and 1.7 x 1.7mm = NCSxE17A). For more information about the dimensions, see Figure 3 and Figure 4 below.

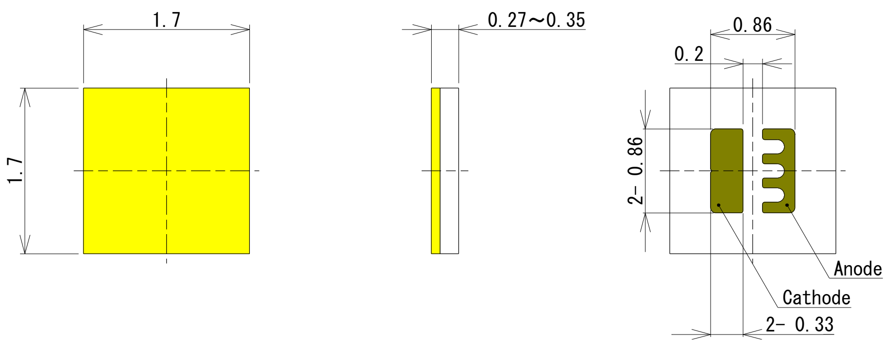


Figure 3. Outline Dimensions of NCSxE17A

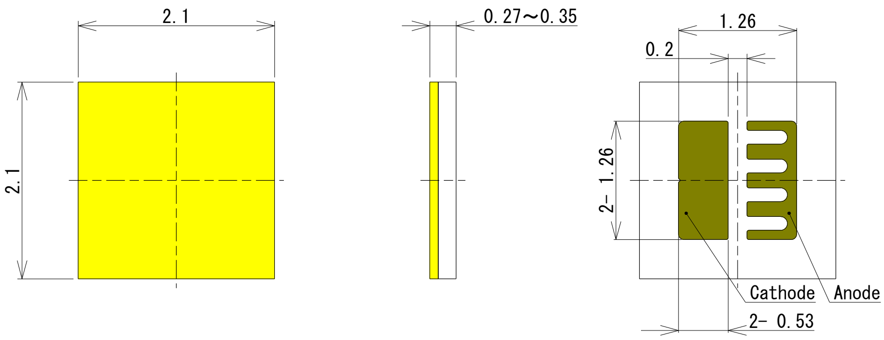


Figure 4. Outline Dimensions of NVSxE21A

The following are major issues and concerns when designing a high-density module:

1) How large of a mounting pitch is needed for the LEDs?
2) What material is suitable for the assembly board?
3) How will the mounting pitch affect the luminous flux of the luminaire?
4) How will the mounting pitch affect the directivity/color uniformity of both the LEDs and luminaire?
5) What is the relationship between the mounting pitch and multi-shadow issues?
6) How will the mounting pitch affect the surface that is illuminated by the luminaire?
7) In order to prevent a reduction in luminous flux, what is the best way to manage the thermal issues for high-density mounting?

3. Considerations for the mounting pitch and configuration between each LED

3.1 Mounting Pitch between each LED for a High-Density Module

When determining the mounting pitch between each LED for a high-density module, it is important to consider the precision of the pick-and-place machine, dimensional tolerances of the package, and tolerances between the package and electrodes. The necessary mounting pitch between each LED is shown in Equation 1.

$$\sqrt{0.1^2(\text{Pick}-\text{and}-\text{Place Machine})+0.05^2(\text{Package})+0.05^2(\text{Package and Electrode})}$$

$$=0.122\text{mm}(\text{One Side})\rightarrow 0.244\text{mm}\fallingdotseq 0.3\text{mm}$$

Equation 1. Required Mounting Pitch between each LED

The answer when solving Equation 1 is approximately 0.3 mm. The potential for the poor alignment of the packages must also be considered, resulting in the recommended minimum mounting pitch between each LED as 0.4 mm.

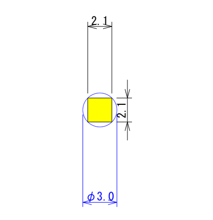
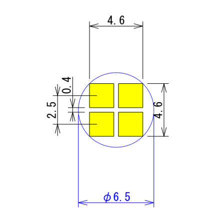
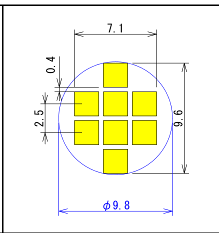
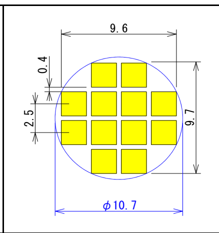
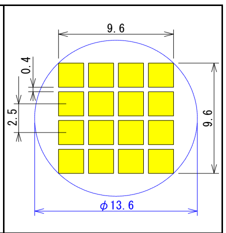
When soldering the LEDs onto a PCB with a small mounting pitch, consider the following and ensure that there are no issues: 1) the clearance between the electrodes of the LED is very narrow and it requires higher precision in placing the LEDs and/or manufacturing the PCBs, 2) the LEDs may not self-align due to the size/shape of the LED electrodes.

For more details about how to mount the LEDs, see Application Note: Assembly Techniques for part number NCSxE17A/NVSxE21A.

3.2 Configuration Examples for High-Density Mounting for NVSxE21A

Table 1 below illustrates some examples of high-density mounting configurations when soldering NVSxE21A LEDs with a pitch of 0.4 mm.

Table 1. High-Density Configuration Examples for NVSxE21A LEDs T_A=25°C

Configuration					
Number of LEDs	1	4	8	12	16
Emission Area Diameter	ϕ3.0mm	ϕ6.5mm	ϕ9.8mm	ϕ10.7mm	ϕ13.6mm
Luminous Flux	(300lm)	(1200lm)	(2400lm)	(3600lm)	(4800lm)

As the above examples show, the LEDs have great flexibility in configuration and engineering design due to the compact size of the package. By changing just the LED configuration, it is possible to achieve any desired LED emission area diameter; this will allow the LEDs to be used for various luminaire designs.

4. Recommendations for PCBs used with NxSxExxA

4.1 Recommendations for the PCB Materials

When soldering the LEDs to a PCB with a small mounting pitch, the LEDs may be exposed to heat generated by surrounding LEDs and become hot. Due to this heat concentration, the luminous flux of the LEDs may decrease, the lifetime may become shorter, and the solder resist of the PCB may discolor; to avoid this, it is important to choose an appropriate PCB material for the chosen application.

If a PCB with low thermal dissipation (e.g. CEM-x and FR-x PCBs) is used for NxSxExxA LEDs, the concentrated heat may not be dissipated sufficiently; Nichia recommends using PCBs with high thermal dissipation (e.g. MCPCBs).

4.2 Recommendations for the Land Patterns

There are two types of land patterns for a PCB solder mask, Non-Solder Mask Defined (NSMD) and Solder Mask Defined (SMD). Since NxSxExxA LEDs require precision for both picking and placing, NSMD pads are recommended. For more details, see Application Note: Assembly Techniques for part number NCSxE17A/NVSxE21A.

5. Optical Evaluation for High-Density Modules Mounted with the LEDs

To verify the optical characteristics of a module with a high density of the LEDs (i.e. light interference, directivity/chromaticity, multi-shadow, and illuminated surface), Nichia performed an evaluation of NCSxE17A (5000K/R8000). For this evaluation, 12 LEDs were mounted on a 25 mm x 25 mm PCB for mounting pitches ranging from 0.2mm up to 1.9mm.

5.1 High-Density Modules that were used for the Evaluation

Table 2 shows the LED configurations and Table 3 shows the board specifications for the PCBs that were used in the evaluation.

Table 2. LED Configurations

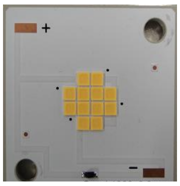
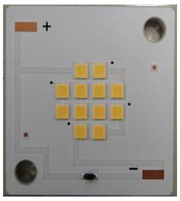
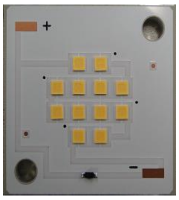
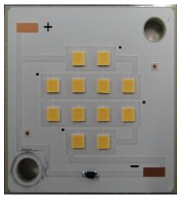
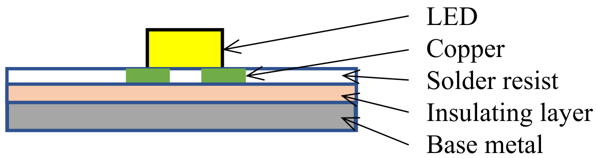
LED Clearance	0.2 mm	0.4 mm	0.9 mm	1.4 mm	1.9 mm
Emission Area Diameter	φ8.2 mm	φ8.9 mm	φ10.4 mm	φ12.0 mm	φ13.6 mm
Configuration					

Table 3. Specifications of the PCBs used

Outline dimensions (mm)			25×25		
Structure					
Land Pattern (Copper)	Thickness	(μm)	35		
	Thermal conductivity	(W/mK)	400		
Solder Resist	-	-	White		
Insulating layer	Thickness	(μm)	120		
	Thermal conductivity	(W/mK)	2.1	11.1	2.7
Base metal	Material	-	Al6063		Cu
	Thickness	(μm)	1.0	2.0	1.0
	Thermal conductivity	(W/mK)	218	218	400

5.2 Effect of the Mounting Pitch on the Luminous Flux

If LEDs are mounted to a module with a narrow pitch, the light from these LEDs may be affected by the adjacent LEDs (e.g. blocked, absorbed, etc.) and it may cause the luminous flux to decrease at the module level. Figure 5 and Figure 6 illustrate how the difference in mounting pitch can affect how the light scatters, or are blocked/absorbed.

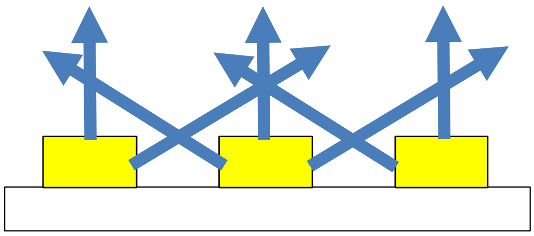


Figure 5. How the light scatters when the mounting pitch is sufficient

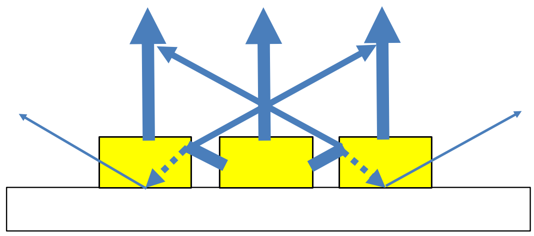


Figure 6. How the light is blocked/absorbed when the mounting pitch is insufficient

As shown in Figure 5, if the mounting pitch is sufficient, the light from each LED may be less affected by the adjacent LEDs. On the other hand, as shown in Figure 6, if the mounting pitch is insufficient, some of the light may be blocked/absorbed and it may cause the overall luminous flux of the module to decrease.

As a result of the above information, there could be a concern when the LEDs are used in a high-density module; Nichia performed an evaluation by using different mounting pitches between 0.2 to 1.9 mm to determine if this concern occurs with these pitches. Table 4 and Figure 7 below show the results of this evaluation. As shown in this table and figure, these mounting pitches do not affect the luminous flux at the module level.

Table 4. Relative Luminous Flux vs. Mounting Pitch

LED Clearance (mm)	0.2	0.4	0.9	1.4	1.9
AL (t=1.0mm)	0.99	1.00	1.00	1.00	1.00
AL (t=2.0mm)	0.99	1.00	1.00	0.99	1.00
Cu (t=1.0mm)	0.99	1.00	1.00	1.00	1.00

Measurement condition
: I_{FP}=350mA, T_A=25°C

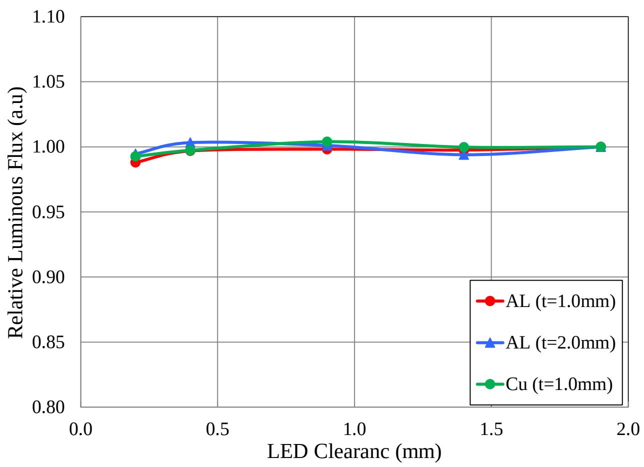
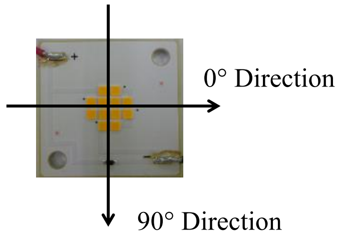


Figure 7. Relative Luminous Flux vs. Mounting Pitch

5.3 Directivity Comparison for Directivity and Color Uniformity



Nichia performed an evaluation to compare the directivity and color uniformity between discrete LEDs and high-density modules. Figure 8 and Figure 9 below show the comparison results.

As shown in the below figures, there is not a noticeable difference between the discrete LEDs and the high-density modules for either the directivity or color uniformity.

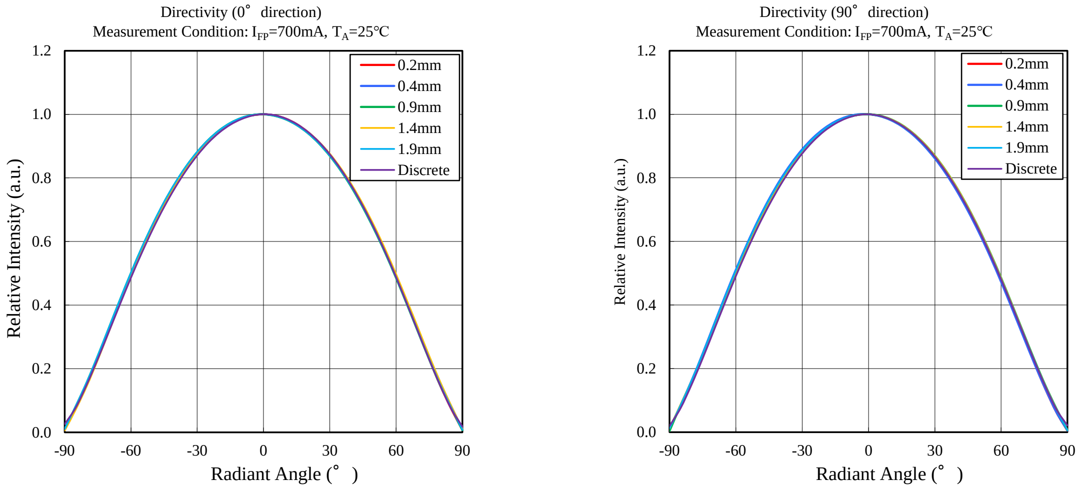


Figure 8. Directivity Comparison

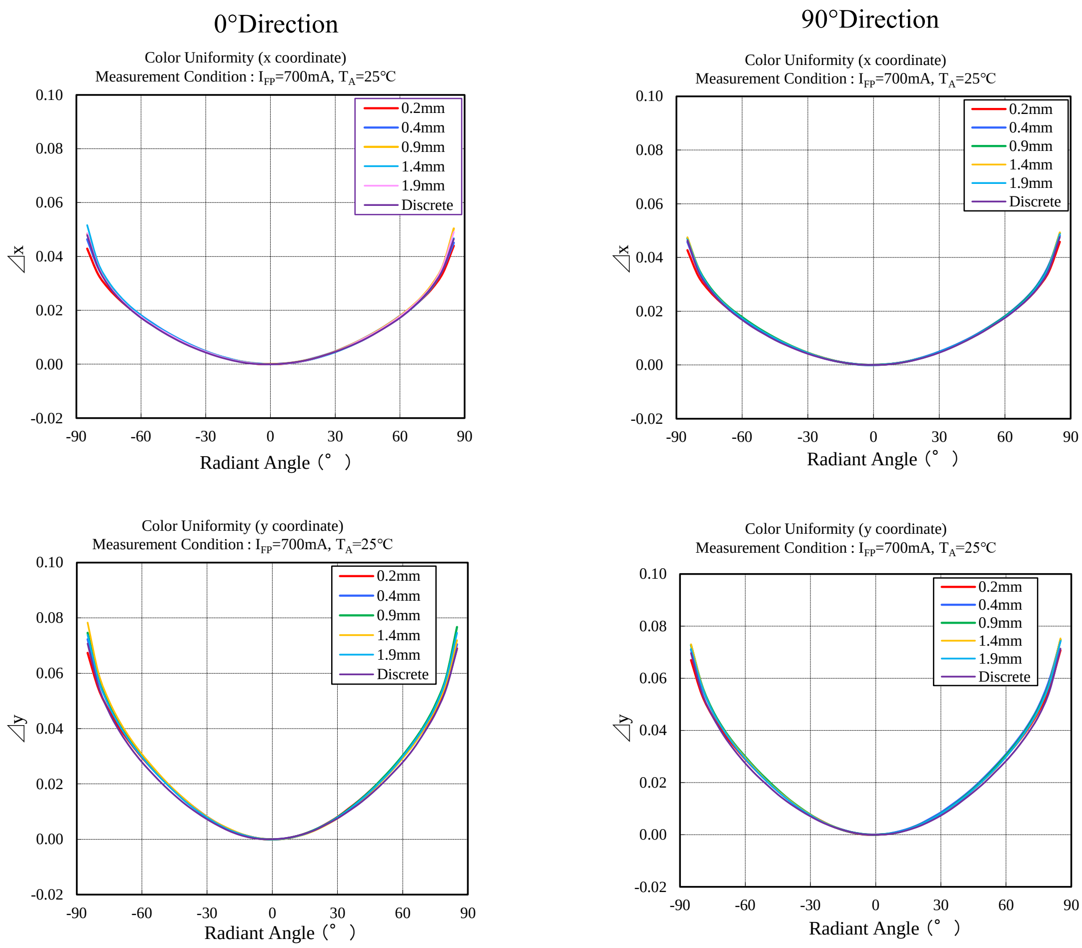


Figure 9. Color Uniformity Comparison

5.4 Design Considerations to Improve the Multi-Shadow Effect

Nichia performed an evaluation to discover what the multi-shadow would look like when both the LED light source and screen are fixed and an object is moved. In this evaluation, high-density modules mounted with the LEDs with different mounting pitches were used as the light source; the light source and screen were fixed in one position and an object was moved to change the distance between the light source/screen and this object. Figure 10 below shows the evaluation settings and Table 5 shows the results.

As shown in Table 5, Nichia confirmed that the narrower the mounting pitch was, the more improved the multi-shadow effect became; the farther the object is, the more distinct the shadow became.

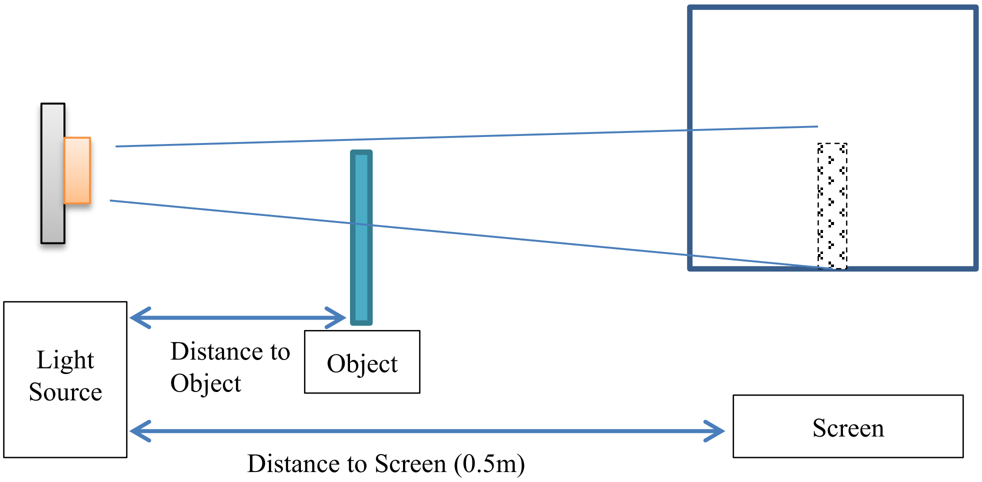
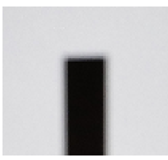
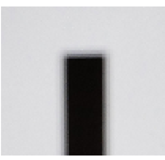
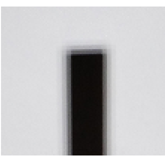
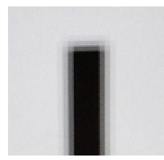
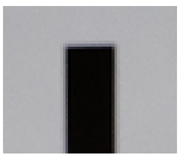
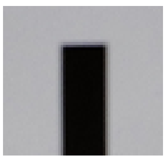
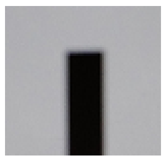
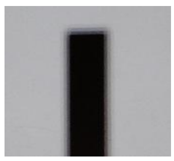
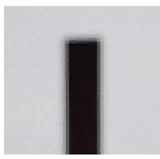
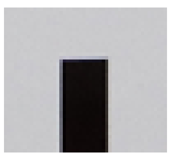
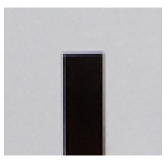
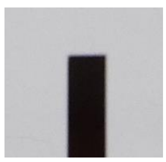
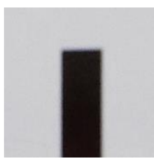


Figure 10. Multi-Shadow Evaluation Method

Table 5. Multi-Shadow Evaluation Results

I_F=50mA, Distance to Screen=0.5m

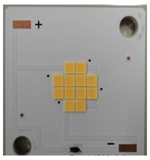
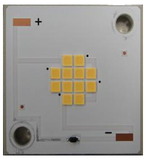
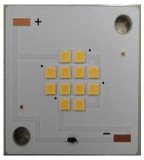
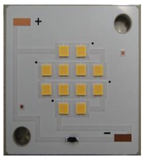
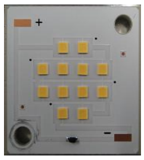
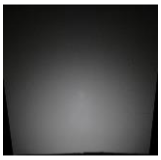
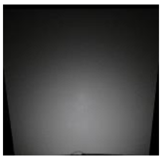
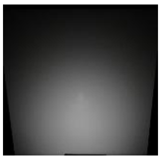
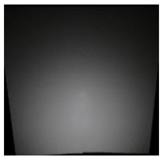
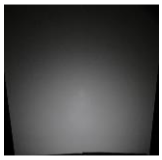
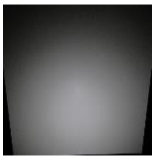
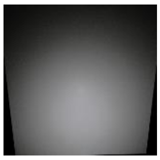
LED Clearance (mm)		0.2	0.4	0.9	1.4	1.9
Distance to Object (m)	0.1					
	0.2					
	0.3					
	0.4					

5.5 Confirmation of the Illuminated Surfaces

Nichia confirmed the differences among the illuminated surfaces in regards to mounting pitch between each LED. The method used for this confirmation is the same as the multi-shadow evaluation method shown in Figure 9 except the object is excluded. The results of the illuminated surface confirmations are shown in Table 6. If the LEDs are mounted with a small mounting pitch, regardless of whether a diffuser lens and/or reflector are used, there is no difference in either the illuminated surface or how the light appears when viewed from the side.

Table 6. Results obtained by illuminating the screen and viewing the light source from the side

I_F=50mA, Distance to Screen=0.5m

LED Clearance (mm)		0.2	0.4	0.9	1.4	1.9
Configuration						
Screen surface illuminated by the light source from the front	(Luminaire) Installed with a lens and reflector					
	(Luminaire) Installed with a reflector only					
	LED Only					
Modules when viewed from the side						
Difference when viewed by the human eye		No variation in color. No difference in the illuminated surface due to the difference in mounting pitch between LEDs.				

6. Thermal Design to Prevent a Reduction in Luminous Flux

If the LEDs are used in a high density module, heat from each LED may concentrate in certain areas of the module and it may cause the luminous flux to decrease. This section discusses the effect of the heat concentration on the luminous flux and how to reduce the heat concentration to avoid a possible decrease in luminous flux.

In order to prevent heat that is generated by LEDs from concentrating on a module, using the LEDs under appropriate conditions/environments are important. To determine those conditions /environments, Nichia conducted an evaluation by using different mounting pitches and PCBs with different thermal resistance values. In this evaluation, Nichia used:

- 12W module operated at I_F=350mA (1W/LED) with a thermal resistance of 2.0°C/W
- 24W module operated at I_F=700mA (1W/LED) with a thermal resistance of 0.5°C/W
- Grease with a thermal conductivity of 0.84W/m·K

For the dimensions and appearance of the above heat sinks, see Figure 11 and Figure 12.

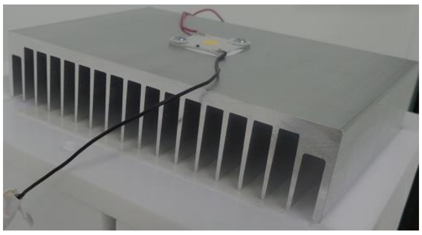


Figure 11. Heat sink with a Thermal Resistance of 2.0°C/W (100 x 143 x 30 mm)

Figure 12. Heat sink with a Thermal Resistance of 0.5°C/W (150 x 294 x 90 mm)

6.1 Evaluation of 12W Modules:
the relationship between the mounting pitch and the reduction in luminous flux

Nichia measured temperatures of 12W modules after operating them for 1 hour. Tables 7 to 9 and Figure 13 show the measurement results.

Table 7. Heat Dissipation Evaluation Results (Aluminum board, thickness=1.0mm)

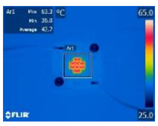
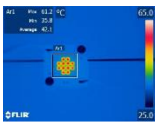
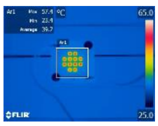
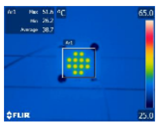
LED Clearance (mm)	0.2	0.4	0.9	1.4	1.9
Heat Distribution					
LED Surface Temperature T_T (°C)	65.5	63.3	61.2	57.4	51.6
PCB Temperature T_B (°C)	37.3	36.6	35.5	35.9	35.1
Thermal Resistance $R_{\theta TB}$ (°C/W)	27	25	24	20	16

Table 8. Heat Dissipation Evaluation Results (Aluminum board, thickness=2.0mm)

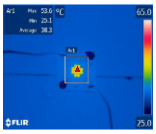
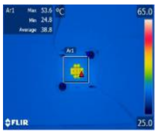
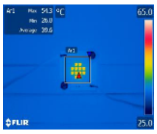
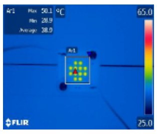
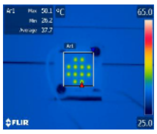
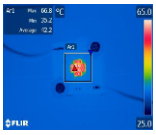
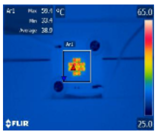
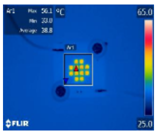
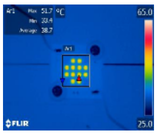
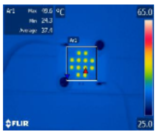
LED Clearance (mm)	0.2	0.	0.9	1.4	1.9
Heat Distribution					
LED Surface Temperature T_T (°C)	53.6	53.6	54.3	50.1	50.1
PCB Temperature T_B (°C)	34.1	34.4	34.8	34.8	34.3
Thermal Resistance $R_{\theta TB}$ (°C/W)	19	18	19	15	15

Table 9. Heat Dissipation Evaluation Results (Copper board, thickness=1.0mm)

LED Clearance (mm)	0.2	0.4	0.9	1.4	1.9
Heat Distribution					
LED Surface Temperature T_T (°C)	66.8	59.4	56.1	51.7	49.6
PCB Temperature T_B (°C)	32.8	33.4	33.2	33.7	35.1
Thermal Resistance $R_{\theta TB}$ (°C/W)	32	25	22	17	14

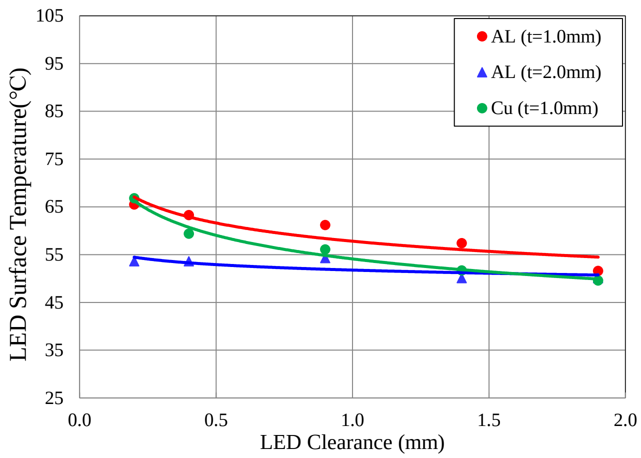


Figure 13. Junction Temperature vs. Mounting Pitch by type of PCB

If the mounting pitch is not appropriate, it can cause heat from the LEDs to concentrate in certain areas. This can be avoided by using a heat sink with a good thermal resistance. To verify the relationship between the mounting pitch, material of the PCB, and the luminous flux reduction, Nichia performed an evaluation. Tables 10 to 12 and Figure 14 below show the evaluation results.

Table 10. Mounting Pitch vs. Reduction in Luminous Flux (Aluminum board, Thickness=1.0mm)

LED Clearance (mm)		0.2	0.4	0.9	1.4	1.9
Luminous Flux (lm)	Lighting time 1.5sec	1702	1717	1719	1718	1722
	Lighting time 1hr	1589	1610	1621	1624	1629
Loss (%)		9.5	6.6	6.2	5.7	5.5

Table 11. Mounting Pitch vs. Reduction in Luminous Flux (Aluminum board, Thickness=2.0mm)

LED Clearance (mm)		0.2	0.4	0.9	1.4	1.9
Luminous Flux (lm)	Lighting time 1.5sec	1722	1737	1733	1721	1731
	Lighting time 1hr	1633	1641	1642	1636	1646
Loss (%)		9.5	9.5	5.2	5.5	5.3

Table 12. Mounting Pitch vs. Reduction in Luminous Flux (Copper board, Thickness=1.0mm)

LED Clearance (mm)		0.2	0.4	0.9	1.4	1.9
Luminous Flux (lm)	Lighting time 1.5sec	1710	1718	1729	1722	1722
	Lighting time 1hr	1594	1618	1631	1632	1631
Loss (%)		9.5	6.8	5.8	5.7	5.2

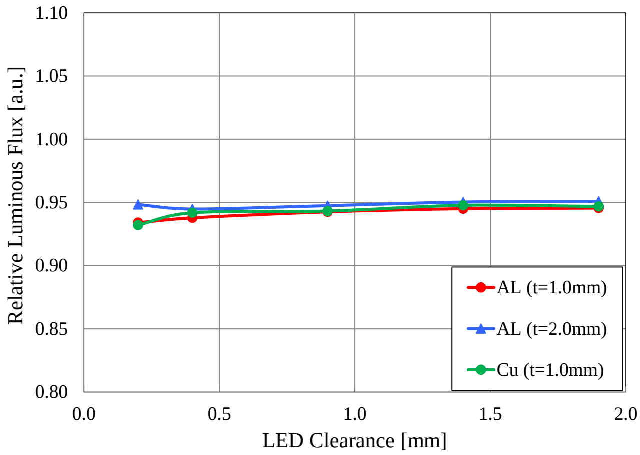


Figure 14. Relative Luminous Flux vs. Mounting Pitch by type of PCB

If the mounting pitch is not appropriate, it can cause heat from the LEDs to concentrate in certain areas and the luminous flux to decrease. This can be avoided by using PCBs with good thermal dissipation.

6.2 Evaluation of 24W Modules: the relationship between the mounting pitch and the reduction in luminous flux

Nichia measured temperatures of 24W modules after operating them for 1 hour. Tables 13 to 15 and Figure 15 show the measurement results.

Table 13. Heat Dissipation Evaluation Results (Aluminum board, Thickness=1.0mm)

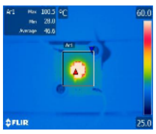
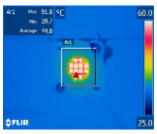
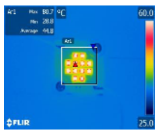
LED Clearance (mm)	0.2	0.4	0.9	1.4	1.9
Heat Distribution					
LED Surface Temperature T_T (°C)	100.5	93.1	91.8	81.7	80.7
PCB Temperature T_B (°C)	37.3	37.2	37.0	37.3	37.3
Thermal Resistance $R_{\theta TB}$ (°C/W)	30	27	26	21	21

Table 14. Heat Dissipation Evaluation Results (Aluminum board, Thickness=2.0mm)

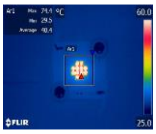
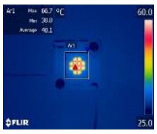
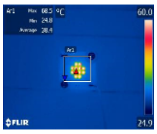
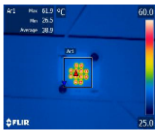
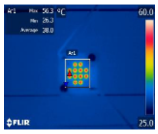
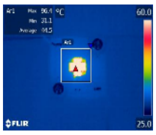
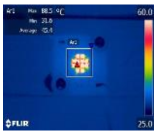
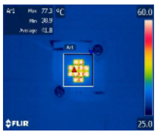
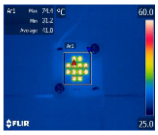
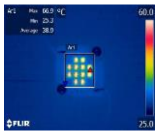
LED Clearance (mm)	0.2	0.4	0.9	1.4	1.9
Heat Distribution					
LED Surface Temperature T_T (°C)	74.4	66.7	68.5	61.9	56.3
PCB Temperature T_B (°C)	25.5	25.4	25.7	25.9	25.9
Thermal Resistance $R_{\theta TB}$ (°C/W)	23	20	20	17	14

Table 15. Heat Dissipation Evaluation Results (Copper board, Thickness=1.0mm)

LED Clearance (mm)	0.2	0.4	0.9	1.4	1.9
Heat Distribution					
LED Surface Temperature T_T (°C)	96.4	85.5	77.3	74.4	66.9
PCB Temperature T_B (°C)	30.5	30.5	29.9	30.7	30.3
Thermal Resistance $R_{\theta TB}$ (°C/W)	31	26	23	21	17

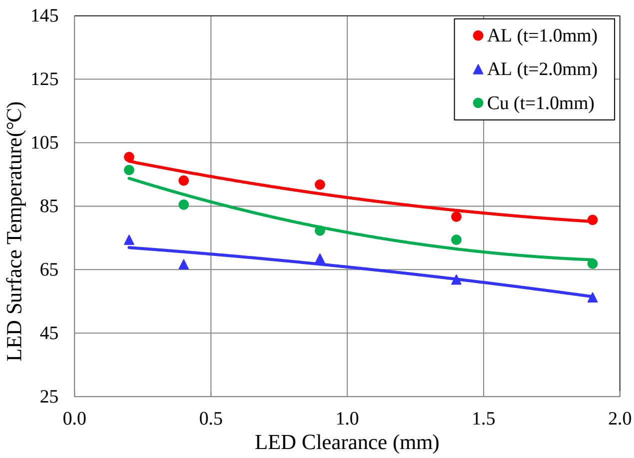


Figure 15. Junction Temperature vs. Mounting Pitch by type of PCB

If a high current is applied to high-density modules mounted with the LEDs, a rapid increase in junction temperature may be observed. To avoid the increase in junction temperature, it is important to select both a PCB with good heat dissipation and appropriate mounting pitch. Nichia evaluated PCBs of different materials (e.g. aluminum and copper) and thicknesses (e.g. 1.0mm and 2.0mm) to determine how these PCBs affect the reduction in luminous flux. Tables 16 to 18 and Figure 16 show the results of this evaluation.

Table 16. Mounting Pitch vs. Reduction in Luminous Flux (Aluminum board, Thickness=1.0mm)

LED Clearance (mm)		0.2	0.4	0.9	1.4	1.9
Luminous Flux (lm)	Lighting time 1.5sec	3054	3047	3070	3072	3081
	Lighting time 1hr	2763	2810	2855	2872	2888
Loss (%)		9.5	7.8	7.0	6.5	6.3

Table 17. Mounting Pitch vs. Reduction in Luminous Flux (Aluminum board, Thickness=2.0mm)

LED Clearance (mm)		0.2	0.4	0.9	1.4	1.9
Luminous Flux (lm)	Lighting time 1.5sec	3089	3104	3102	3070	3093
	Lighting time 1hr	2902	2927	2926	2917	2931
Loss (%)		9.5	6.0	5.7	5.7	5.0

Table 18. Mounting Pitch vs. Reduction in Luminous Flux (Copper board, Thickness=1.0mm)

LED Clearance (mm)		0.2	0.4	0.9	1.4	1.9
Luminous Flux (lm)	Lighting time 1.5sec	3070	3065	3095	3084	3086
	Lighting time 1hr	2773	2849	2889	2895	2899
Loss (%)		9.5	9.7	7.0	6.6	6.1

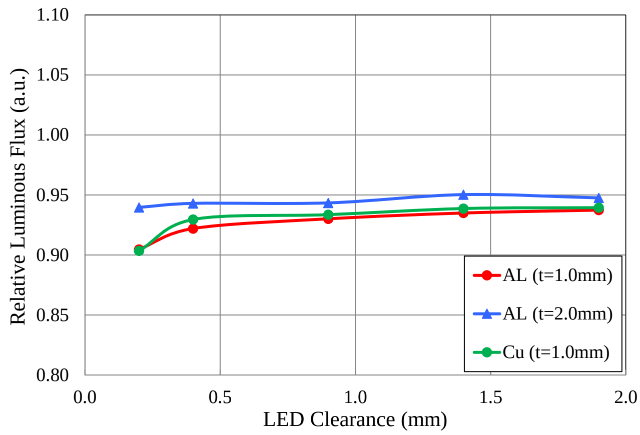


Figure 16. Relative Luminous Flux vs. Mounting Pitch by type of PCB

If a high current is applied to the LEDs that are mounted with a narrow pitch, even if operated under conditions/environments where the heat is sufficiently dissipated, it may cause the luminous flux to decrease significantly. In order to maintain a sufficient luminous flux, it is important to select both an appropriate PCB and mounting pitch.

* The junction temperatures or T_J in this section were determined by measuring the package surfaces, instead of the dice, with a thermal imaging camera. If a thermal imaging camera is used in temperature measurement for the chosen application, ensure that a thermocouple is used in the measurement along with the thermal imaging camera to ensure that these temperatures are consistent.

7. Evaluations for Examples of High-Density Modules

This section provides some examples of high-density modules to illustrate the issues discussed in the previous sections and includes the evaluation results of these modules. The modules were designed to achieve 700lm with a diameter of φ20mm and is operated at 500W at T_J=85°C. For the details of these modules, see Table 19 below.

Table 19. Specifications for the Example Test Modules

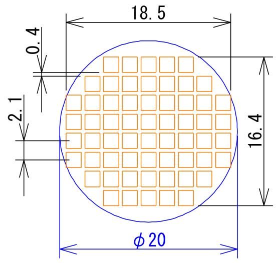
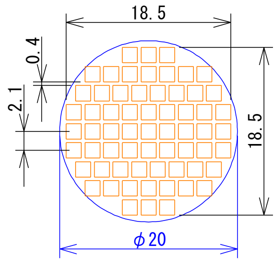
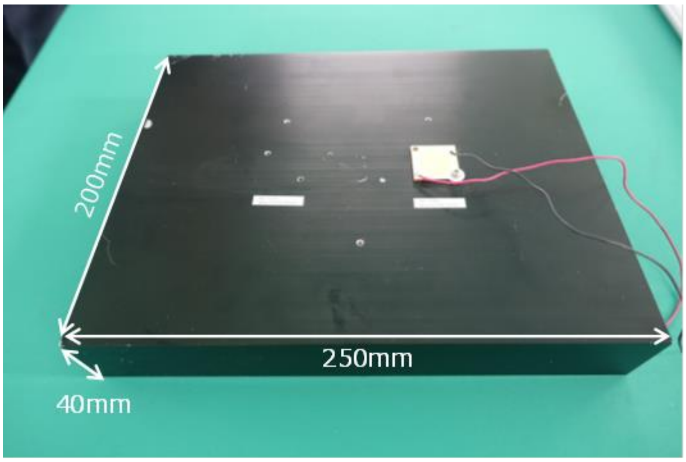
		Package dimension: 1.7mm, Color temperature: 4000K, Ra>70	
LED Configuration			
Mounting Pitch		0.4 mm	
Number of LEDs		60pcs	63pcs
Conditions		Target Luminous Flux 7000lm (operated at 50W, T_J=85°C)	
Luminous Flux	(lm)	7003	7020
Forward Current	(mA)	295	280
Watts	(W)	50.3	50.0
Luminous Efficacy	(lm/W)	139	141

Figure 17 below shows the appearance and specifications of the heat sink that was used for the modules to dissipate heat.



T_A = 25°C
Heat sink: 0.33°C/W
Grease: 9.0W/m·K

PCB
Material: Copper (Cu)
PCB thickness: 1.5 mm
Insulating Layer thickness: 120μ m (3W/m·K)
Land Pattern (Copper) thickness: 35μm

Figure 17. Heat sink used for the Evaluation

Nichia measured the characteristics of the test modules as they were mounted on the heat sink. For the measurement results, see Table 20 below.

Table 20. Measurement Results of the Test Modules

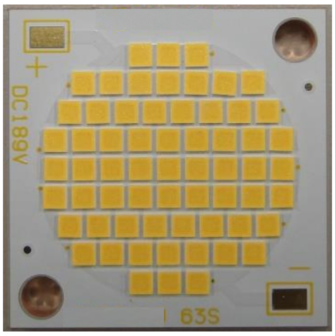
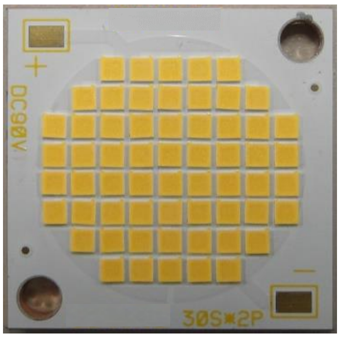
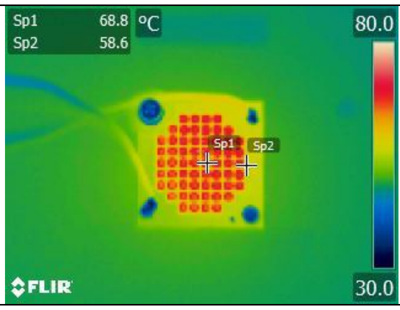
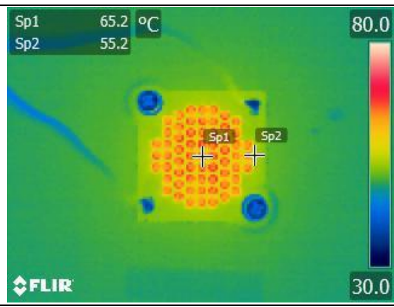
	Package dimension: 1.7mm, Color temperature: 4000K, Ra>70					
LED Configuration						
Mounting Pitch	0.4 mm					
Number of LEDs	60pcs			63pcs		
Conditions (Forward Current (I_F), Emission Duration)	I_F=295mA			I_F=280mA		
	Calculated Value	Measured Value		Calculated Value	Measured Value	
		1.5sec	1hr		1.5sec	1hr
Luminous Flux (lm)	7003	7723	7502	7020	7759	7560
Watts (W)	50.3	51.6	50.2	50.0	51.2	49.8
Luminous Efficacy (lm/W)	139	150	149	141	152	152
Junction Temperature T_J (°C)	85	-	-	85	-	-

Table 21 below shows thermal images that illustrate how the heat is distributed over the surfaces of the modules. Based on these images, when a current that flows through a LED is smaller, heat becomes less concentrated.

Table 21. Distribution of heat on the test module surfaces

	Package dimension: 1.7mm, Color temperature: 4000K, Ra>70	
Mounting Pitch	0.4 mm	
Number of LEDs	60pcs	63pcs
Conditions	I_F=295mA	I_F=280mA
Heat Distribution		
PCB Temperature T_B (°C)	58.6	55.2
LED Surface Temperature T_T (°C)	68.8	65.2
Thermal Resistance $R_{\theta TB}$ (°C/W)	12.2	12.6

8. How to Protect the LEDs from ESD Damage: Protection Devices

Since NxSxExxA LEDs do not have internal protection devices, to protect the LEDs from ESD damage it is recommended to use the LEDs with a protection device on a module. Nichia has performed two kinds of electrostatic discharge (ESD) tests (i.e. HBM and MM) on both modules mounted with the LEDs and a protection device and modules mounted with the LEDs without a protection device and verified that if a protection device is not used in the module, even a low voltage may be able to damage the LEDs and/or cause them not to illuminate. Table 22 and Table 23 below show the test results.

*These results do not guarantee the reliability or performance of the LEDs. Ensure that an appropriate protection device is selected and/or necessary tests are performed for the chosen application.

Table 22. ESD Tests (HBM) HBM, 1.5kΩ, 100pF, 1 pulse, alternately positive or negative

Protection device (i.e. ZD)	Direction of I_F	Maximum voltage (kV)	Results
With ZD	Positive	10	Pass
	Negative	10	Pass
Without ZD	Positive	10	Pass
	Negative	1.7	Fail

Table 23. ESD Tests (MM) MM, 0Ω, 200pF, 1 pulse, alternately positive or negative

Protection device (i.e. ZD)	Direction of I_F	Maximum voltage (kV)	Results
With ZD	Positive	4	Pass
		4	Pass
	Negative	4	Pass
		4	Pass
Without ZD	Positive	1.1	Fail
		1.4	Fail
	Negative	1.2	Fail
		1.5	Fail

9. Summary

As the previous sections have discussed, Nichia has confirmed that for the NxSxExxA LEDs

1) the mounting pitch does not have an effect on the optical characteristics of the modules,
2) if the mounting pitch is smaller, more heat can concentrate in certain areas on the module surface; it can cause a further reduction in luminous flux at the module level,
3) if the LEDs are used in conditions/environments where heat is sufficiently dissipated, as verified by the examples of high density modules in Section 7, the heat concentration in certain areas of the module can be reduced and the reduction in luminous flux can be improved at the module level.

When designing a high-density module that uses NxSxExxA LEDs, give sufficient consideration to the issues discussed in this application note and perform further evaluation to determine the specifications/design of the chosen application (e.g. mounting pitch, thermal design of the module, etc.).

Light Emitting Diode

Disclaimer

This application note is a controlled document of Nichia Corporation (Nichia) published to provide technical information/data for reference purposes only. By using this application note, the user agrees to the following:

- This application note has been prepared solely for reference on the subject matters incorporated within it and Nichia makes no guarantee that customers will see the same results for their chosen application.
- The information/data contained herein are only typical examples of performances and/or applications for the product. Nichia does not provide any guarantees or grant any license under or immunity from any intellectual property rights or other rights held by Nichia or third parties.
- Nichia makes no representation or warranty, express or implied, as to the accuracy, completeness or usefulness of any information contained herein. In addition, Nichia shall not be liable for any damages or losses arising out of exploiting, using, or downloading or otherwise this document, or any other acts associated with this document.
- The content of this application note may be changed without any prior or subsequent notice.
- Copyrights and all other rights regarding the content of this document are reserved by Nichia or the right holders who have permitted Nichia to use the content. Without prior written consent of Nichia, republication, reproduction, and/or redistribution of the content of this document in any form or by any means, whether in whole or in part, including modifications or derivative works hereof, is strictly prohibited.

NICHIA CORPORATION 491 Oka, Kaminaka-Cho, Anan-Shi, TOKUSHIMA 774-8601, JAPAN
http://www.nichia.co.jp Phone: +81-884-22-2311 Fax: +81-884-21-0148