Street Lighting with LED Light Sources

Application Note

Abstract

The following application note provides an insight into street lighting with LED light sources. Some possible lighting designs with the Golden DRAGON® OVAL and an OSTAR-Lighting with Fraen reflector for a flexible design solution are presented.

Review of street lighting standards

Each country has its own set of requirements for street lighting applications. In addition, the requirements are divided into different categories as well, requiring a considerable amount of investigation before beginning the design of a street lighting fixture. In the following, summaries and examples of the standards in the various countries are presented.

European (German) standard

DIN EN 13201 – Road lighting, consists of four separate sections as follows:

DIN 13201-1 Road lighting – selection of lighting classes (only applicable for Germany), DIN EN 13201-2 Road lighting – performance requirements, DIN EN 13201-3 Road lighting – calculation of performance, and DIN EN 13201-4 Road lighting – methods of measuring lighting performance. In the above standards, the requirements define specific values with respect to luminance, illuminance, uniformity and further requirements in categories including measurement and calculation methods as well as the appearance of the lighting installations. General specifications for applications which conform to the standards are listed in the following table.

Class	Definition	E_v [1]	U_0 [2]
ME	Motorized vehicles on main roads: Medium speed (30-60 km/h) to high speed (>60 km/h)	0.2 cd/m² to 2.0 cd/m²	0.4
CE	Motorized vehicles in conflict areas: Low speed (5-30 km/h)	7.5 lx to 50 lx	
S	Others: Pedestrian ways, emergency lanes, bicycle lanes, parking areas etc.	2 lx to 15 lx	

1) $\bar{E}_v$: vertical illuminance; Calculation points for the vertical illuminance shall be located in a plane 1,5m above the surface of the road. Vertical illuminance varies with the direction of interest. Usually, it is parallel to the main directions of pedestrian movement (longitudinal direction of the road).

2) U_0: overall uniformity is the ratio of the lowest luminance to the average luminance of the relevant area.

Table 1: Example of German standard

In terms of disability glare, its restriction is specified by a calculated value of Threshold Increment (TI) for ME class, but, in case that the TI value cannot be calculated especially for CE class, it is restricted by installed luminous intensity classes (G classes) in cd/klm at certain angles from downward vertical line. And, for S class, discomfort glare is restricted by glare index classes (D classes) in cd/m, which is a combination of maximum luminous intensity at an angle of 85° from downward vertical line and apparent area of luminous part.

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The European standard does not specify the values for road width, pole height, or pole to pole distance.

Chinese standard

中华人民共和国行业标准 城市道路照明设计标准

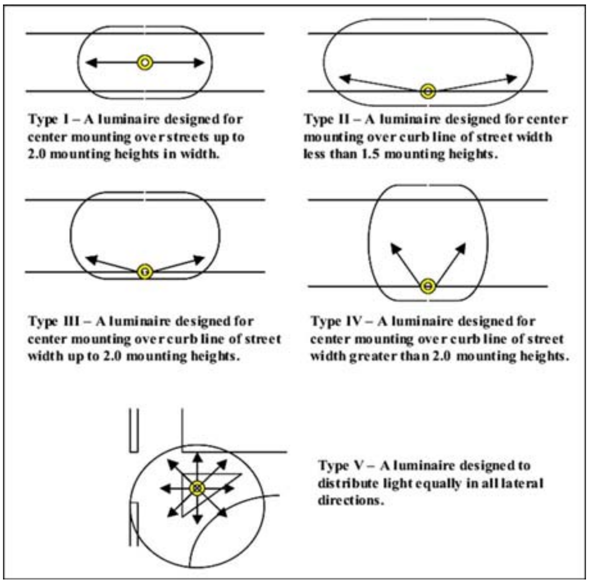
- Road criteria
  - Urban road
    - Expressway
    - Arterial road 30/50 lx
    - Secondary trunk road 20/30 lx
    - Branch road 15/20 lx
    - Residential road
  - Conventional road lighting
    - Lamp height <15m
  - High mast lighting
    - Lamp height ≧20m
  - Semi-height lighting
    - Lamp height 15-20m
- Glare: Cut-off luminaire:
  - maximum intensity
    - 90°, 10cd/1000lm
    - 80°, 30cd/1000lm
- Uniformity 0.4
- Pavement illumination standard
  - Classified by pedestrian flow at night (3 classes) and area (2 classes)
  - Avg. illuminance 5-20 lx
  - E_{max}/E_{min} 1-7.5
  - Min. illuminance 1-4 lx
- Road width, pole to pole distance
  - This standard does not define road width and pole to pole distance.

US standard

ANSI/IESNA RP-8-2000 – American National Standard Practice Roadway Lighting

- Road criteria
  - Freeway
  - Expressway
  - Major
  - Collector
  - Local
  - Bikeway
  - Pedestrian
  - Intersections (only illuminance)
- Road surface classifications for pavement
  - Four classes (from mostly diffuse to mostly specular)
- Requirements
  - Illuminance (e.g. 3-15 lx)
  - Luminance (e.g. 0.3-1.2 cd/m2)
  - Uniformity of the above
  - Veiling luminance ratio
- Glare
  - The glare level is not provided by the standard, and it is described as just information
- Road width, pole heights, pole to pole distance

There are certainly many different road types and pole heights and spacings. It is hard to summarize also here. It is defined by each self-governing body. A following figure shows some examples.



Japanese standard: JIS

- JIS Z9110 Recommended levels of illumination
- JIS Z9111 Lighting for roads
- JIS Z9116 Lighting of tunnels for motorized traffic
- Lighting Classes
  - Motorway
  - Main arterial road
  - Supplementary arterial road

Pavement

- Requirements
  - Luminance
  - Illuminance
  - Uniformity
  - Limitation of glare
    - Maximum glare level is provided for each criteria
  - Surround ratio
  - Glare
  - Road width, pole heights, pole to pole distance

The above requirements are defined by road type. There are certainly many different road types.

Why are LEDs suitable for street lighting?

LEDs offer the following advantages when used as light sources in street lighting applications:

- Long and predictable lifetime
  ⇒ Long and predictable service intervals
  ⇒ Reduced maintenance costs
- Reliability
  ⇒ Increased road safety
- Low power consumption
- Dimming
  ⇒ Adjusting to specific light levels
  ⇒ Reducing energy consumption and light pollution
- Small package size
  ⇒ Flexible, flat and compact lamp design
- High color rendering (CRI)
- Mixing of yellow and white LEDs
  ⇒ Flexibility in color temperature and CRI
- Available color temperature range
- Quick turn on / off
- No problem with hot ignition
  ⇒ Turn on / off without time delay
- 'Unbreakable' LED package
  ⇒ No safety screen for luminaire necessary
- RoHS compliant product (Hg, Pb-free)
  ⇒ Easy lamp recycling
- Higher light output even at low temperatures
- Less attraction to nocturnal insects
  ⇒ Long and predictable service intervals
  ⇒ Reduced maintenance cost
- Easy to design non-glare lighting equipment
  ⇒ Reduction of light pollution

As can be seen from the advantages listed above, the use of LEDs as a light source offers many possibilities to improve upon the quality of street lighting in lighting fixture design.

Nocturnal Insects

Unlike humans, insects are sensitive to the UV-blue and green region of the light spectrum.
Nocturnal insects are attracted to the emission of UV-blue and green light from conventional light sources.

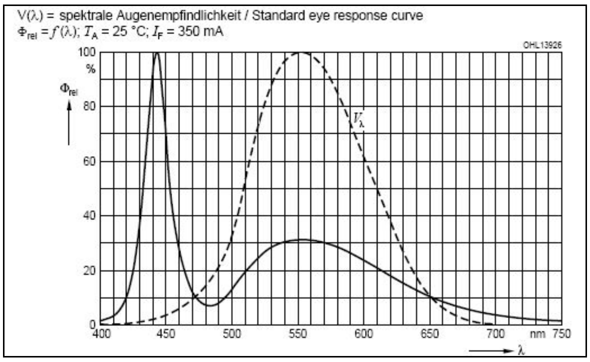


Figure 1: Relative spectral emission of a white LED (e.g. LUW W5AM)

White LEDs, however, emit light in a small peak in the blue range and smaller in the green range, so nocturnal insects are less attracted to such light sources.

This offers long and predictable service intervals for LED-based light fixtures as they achieve less insectural dirt.

Specifics/Peculiarities - glare effects and light pollution

Current light sources emit light across the entire angle, leading to excess glare and light pollution of the sky if the fixture is not carefully designed.

On the other hand, LEDs radiate light over a limited range and the emission can be easily redirected.
Thus, it is comparatively easy to control the direction of light from the LED and reduce the amount of glare, resulting in energy savings due to a more efficient fixture design.

Comparison of light sources

Table 2 shows the comparison of light sources for street lighting.

As example of a LED lamp a design composed of 100 single LEDs with an optical efficiency of 55lm/W was used as a basis for comparison.

In the comparison with the other lamp types the excellent applicability of the LED technology relating to street lighting appears already with these LEDs in particular concerning power dissipation, brightness, color reproduction index and also life time.

These applicability and advantages of the LED technology will be further extended and enlarged by the continuous enhancements in the fields of semiconductor and housing technology in future.
Today latest versions of white LED already exhibit remarkable higher efficiencies, and reach values of nearly 100lm/W.

Total cost in comparison to conventional lighting

Nowadays, the investment required for LED light sources over their entire product life is competitive with conventional lamps.
The initial cost for an LED lamp is much higher than that for a HPS lamp. However, due to the high maintenance costs and system efficiency of the HPS lamp, the total cost for HPS lamp is assumed to be higher than that for the LED lamp over its lifetime, while product lifetimes are expected to be to be nearly the same.
Since the bulb of the HPS lamp must be changed every three years, the cumulative costs for HPS lamp are assumed to be higher than that for LED lamp after a period of 3 or 4 years.

With the continuous improvement of LED performance and cost reduction of LED products, this crossover point can be expected to occur even earlier in the future.

Lamp Type	Power consumption [W]	Luminous Flux [x 1000 lm]	Efficacy [lm/W]	CRI (color reproduction index)	Lifetime [x 1000 hr]
High Pressure Sodium	35 - 400	1.3 - 55	39 - 140	20 - 40	24
Metal Halide	35 - 400	3.4 - 32	70 - 90	60 - 90	6
High Pressure Mercury	50 - 400	1.8 - 22	35 - 90	40 - 60	8 - 12
Low Pressure Sodium	18 - 90	1.8 - 15	100 - 160	<20	16 - 30
Compact Fluorescent	5 - 55	0.25 - 4.8	50 - 88	40 to >90	9
LED (Golden DRAGON® with Oval lens, 100pcs., during operation at 350mA)	112	7	55	80	10 - 50 (50% light decrease)

Table 2: Comparison of various light sources

OSRAM Opto Semiconductors LEDs suitable for street lighting

Of the many LED products offered by OSRAM Opto Semiconductors, the DRAGON® and OSTAR-Lighting products are predestined for street lighting applications.

Table 4, lists a few promising LED products along with their specifications.

- Golden DRAGON® with OVAL lens
- Golden DRAGON® with ARGUS lens
- Golden DRAGON® Plus
- OSTAR-Lighting

The Golden DRAGON® LEDs are single chip packages that provide a typical luminous flux of 82 lm @350 mA (105 lm with Golden DRAGON® Plus). On the other hand, the OSTAR-Lighting consists of multiple LED chips (4 or 6 dies) within a single package, providing a typical luminous flux of 895 lm @700 mA with the 6-die version.

And, as shown in Figures 4 through 7, due to the characteristics of the primary lenses, the suitable DRAGON® LEDs have a wide radiation angle in order to provide better uniformity of illuminance on the target surface, while the OSTAR-Lighting has an almost Lambertian radiation pattern.

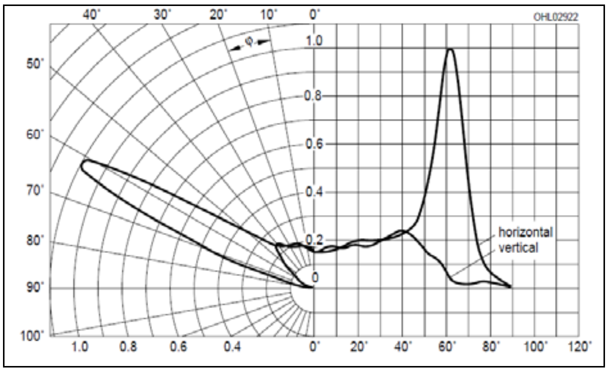


Figure 4: Radiation pattern of the Golden DRAGON® with OVAL lens

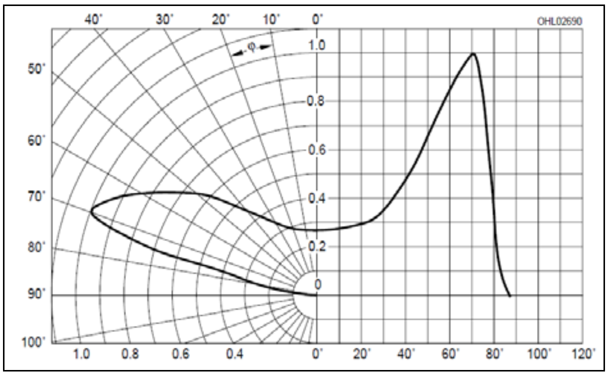


Figure 5: Radiation pattern of the Golden DRAGON® with ARGUS lens

The Golden DRAGON® with an OVAL lens has an asymmetric, oval-shaped radiation pattern which makes it especially suitable for use as a light source for street or tunnel lighting applications, without requiring additional optics.

LED	Type designation	Power consumption	Luminous flux (typ.)	Efficacy (@ 350mA)	Viewing angle
Golden DRAGON® with Oval lens	LUW W5JM	1.1 W	82 lm	74 lm/W	horizontal 120° vertical 80°
Golden DRAGON® with Argus lens	LUW W5KM	1.1 W	82 lm	74 lm/W	160°
Golden DRAGON® Plus	LUW W5AM	1.1 W	105 lm	93 lm/W	170°
OSTAR-Lighting	LE UW E3B	14.6 W	895 lm	65 lm/W	130°

Table 4: Examples of LED products suitable for street lighting

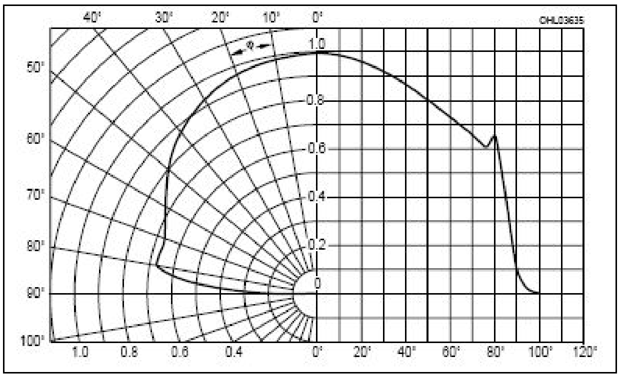


Figure 6: Radiation pattern of the Golden DRAGON® Plus

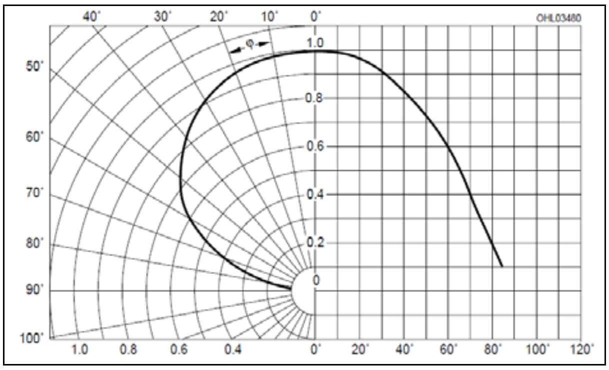


Figure 7: Radiation pattern of the OSTAR-Lighting (LE UW E3B)

Exemplary lighting fixture designs with the Golden DRAGON® with OVAL lens (LW W5JM) and the Golden DRAGON® ARGUS (LW W5KM) are shown in Figures 8 and 9.

Figure 8: Street lamp with the Golden DRAGON® with Oval lens (LW W5JM)

The OSTAR-Lighting requires additional optics in order to efficiently utilize the entire light output, e.g. with an optic for elliptical beam shaping, however. In such cases, there are several solutions from OSRAM Opto Semiconductors 'LED Light for you' (LLFY) partners which offer standard optical products that can be easily installed in order to achieve the desired optical performance.

Figure 9: Street lamp with 54 Golden DRAGON® ARGUS LEDs (LW W5KM) and reflector

Thermal Consideration

In order to ensure high reliability and optimal performance for LED light sources appropriate thermal management is necessary (see also application notes "Thermal Management of Golden Dragon LED" and "OSTAR-Lighting").

Basically, the maximum allowable junction temperature of the individual LED light sources should not be exceeded, as this can lead to irreversible damage to the LED and spontaneous failures.

Furthermore for the use in street lighting applications it is recommended to keep the junction temperature of the LED as low as possible to obtain a high lifetime (see also note “Reliability and Lifetime of LEDs”).

Based on that in a design with plastic housing the passive cooling element should be directly connected to the backside of the isolated metal core board (IMS-PCB).

Figure 10: Example of a street light with plastic housing and passive cooling element (source: SED)

By contrast a direct connection of the IMS-PCB to the surrounding housing is feasible if the lamp is composed of metal.

Figure 11: Example of a street light with metal housing and integrated cooling fins (source: Softray)

Optical simulation

A simulation was performed using the freeware program DIALux, to demonstrate a possible street lighting design with OSRAM Opto Semiconductors LED products.
Figure 12 shows a model for the simulation.

Figure 12: Street lighting model

In this calculation, the following criteria were assumed, based on the Japanese standard:

- > 2 lx at the pavement

  (recommendation for residential streets in Japan so that it is possible to recognize person’s action from a distance of 4 m.)

- > 10 lx at the roadway

  (technically equivalent to the requirement described in JIS for a roadway with a concrete surface)

The following conditions were used for the calculation:

Pavement width: **4 m**
Roadway width: **8 m**
Pavement light height: **4.5 m**
Roadway light height: **10 m**
Pavement light pitch (pole): **20 m**
Roadway light pitch (pole): **25 m**
Arrangement of pavement lighting pole: **single-sided**

Arrangement of roadway lighting pole: **alternate, double-sided**

- Light source example for pavement lighting fixture**:**

  Golden DRAGON® with OVAL lens (LW W5JM, 60 lm), 15 pieces per fixture;

- Light source example for pavement lighting fixture (another case)**:**

  Golden DRAGON® Plus (LUW W5AM, 121 lm), 15 pieces per a fixture;

- Light source example for roadway lighting fixture:

  OSTAR-Lighting (LE UW E3B, 865 lm) with reflector (Fraen FRC M1), 10 pieces per fixture;

The overall radiation pattern of the combination of the OSTAR-Lighting product and the reflector is shown in Figure 13.

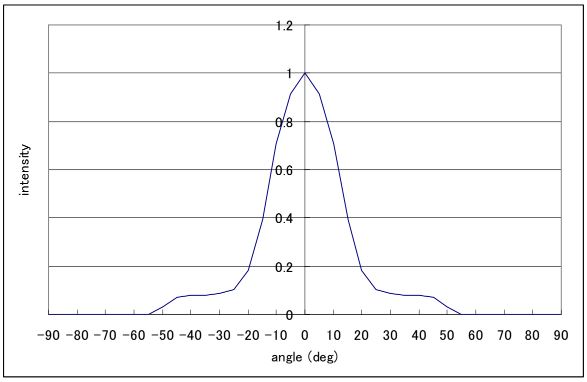


Figure 13: Radiation pattern of the OSTAR-Lighting with a reflector (Fraen FRC M1)

The calculated illuminance at the pavement and roadway are illustrated in the contour graphs in Figures 14 and 15.

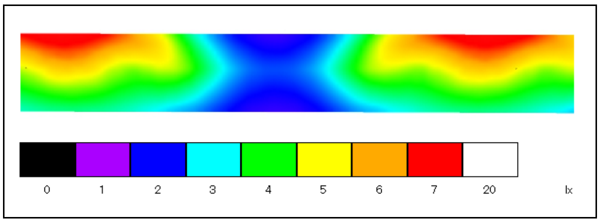


Figure 14(a): Illuminance at pavement (by Golden DRAGON® with OVAL lens)

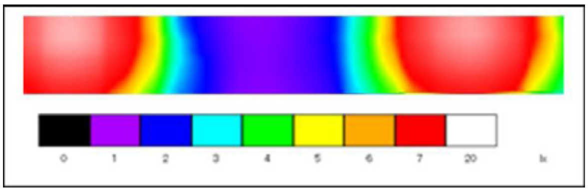


Figure 14(b): Illuminance at pavement (by Golden DRAGON® Plus)

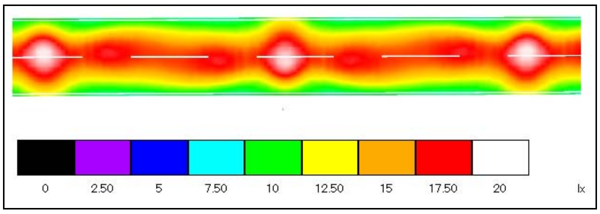


Figure 15: Illuminance at roadway (by OSTAR-Lighting)

As shown by the above results, it was found that with feasible product specifications, it is possible to design a street lighting fixture using LED light sources which meets the criteria of more than 2 lx at the pavement and more than 10 lx at the roadway. A rendering of the simulation result is shown in Figure 16.

Figure 16: Simulation result

In the above simulation, efficiencies (percentage of luminaire luminous flux arriving on the street) are:

pavement (LW W5JM)	33.8%
pavement (LUW W5AM)	18.2%
roadway (LE UW E3B with reflector Fraen FRC M1)	32.4%

Summary

LEDs have many advantages in comparison to current light sources - high-pressure sodium, metal halide, high-pressure mercury, low-pressure sodium, and compact fluorescent lamps. An LED is especially environmentally friendly, due to its high efficiency, long lifetime and low maintenance requirements.

When designing a street lighting fixture, the minimum requirements must be met in each lighting category for the specific country. In addition, other factors must be taken into consideration such as glare or appearance. LEDs also offer several advantages in these areas, compared to conventional light sources, since the light output can be directed and controlled.

With the use of DIALux, it was demonstrated that it is possible to design a street lighting fixture using OSRAM Opto Semiconductors LED products - the Golden DRAGON® with OVAL lens, the Golden DRAGON® Plus and the OSTAR-Lighting which can provides more than 2 lx at the pavement and more than 10 lx at the roadway.

Appendix

Don't forget: LED Light for you is your place to be whenever you are looking for information or worldwide partners for your LED Lighting project.

www.ledlightforyou.com

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About OSRAM Opto Semiconductors

OSRAM Opto Semiconductors GmbH, Regensburg, is a wholly owned subsidiary of OSRAM GmbH, one of the world's three largest lamp manufacturers, and offers its customers a range of solutions based on semiconductor technology for lighting, sensor and visualisation applications. The company operates facilities in Regensburg (Germany), San José (USA) and Penang (Malaysia). Further information is available at www.osram-os.com.